Agroecological transformation of tropical livestock production through cultivating improved forages in integrated crop-tree-livestock systems

An Notenbaert et al., Tropical Forages Program

WAAP Plenary session on "Biodiversity as a lever for sustainable animal production"

Lyon, France - 27 August 2023

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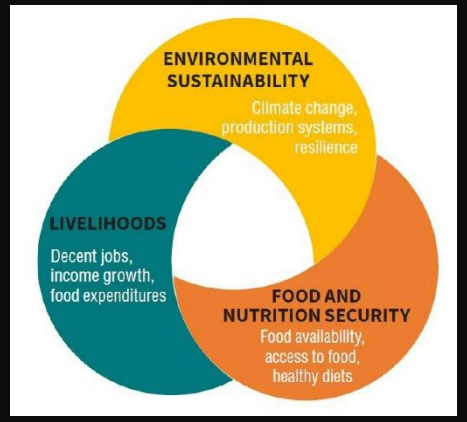
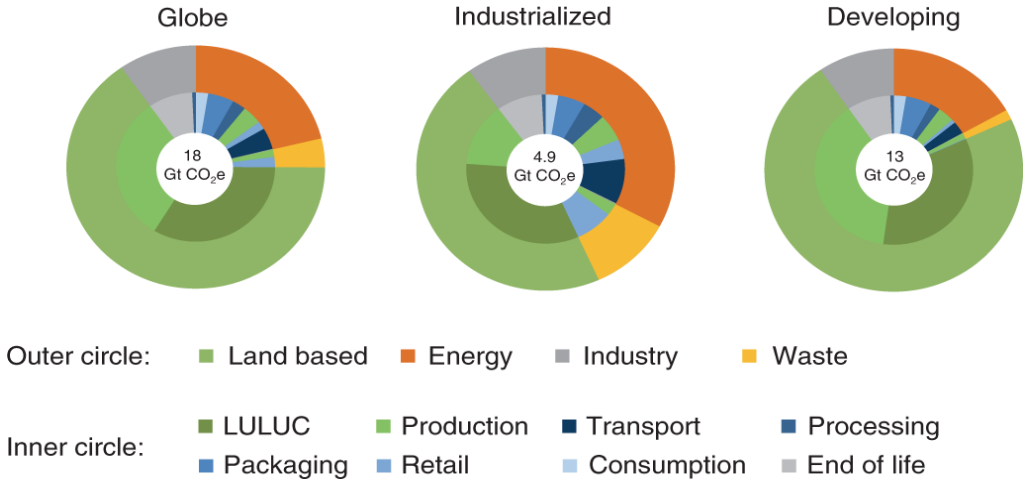
OUR WORLD TODAY

Poverty
Inequality
Food and nutrition insecurity
Climate change
Biodiversity loss
Pollution



Growing sense of URGENCY

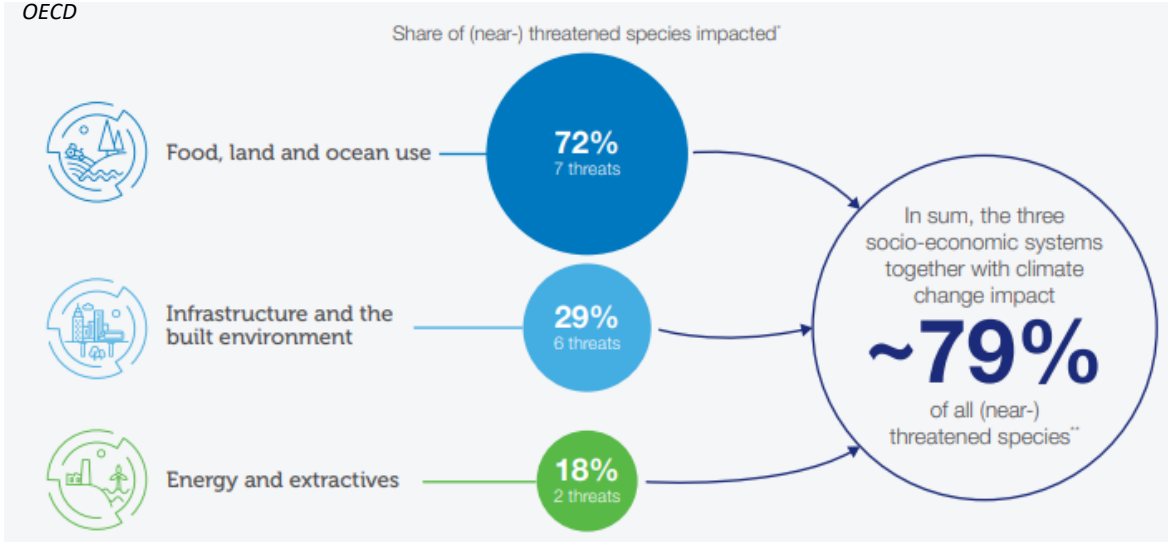
Crippa et al. 2021



GHGe

BIODIVERSITY

OECD

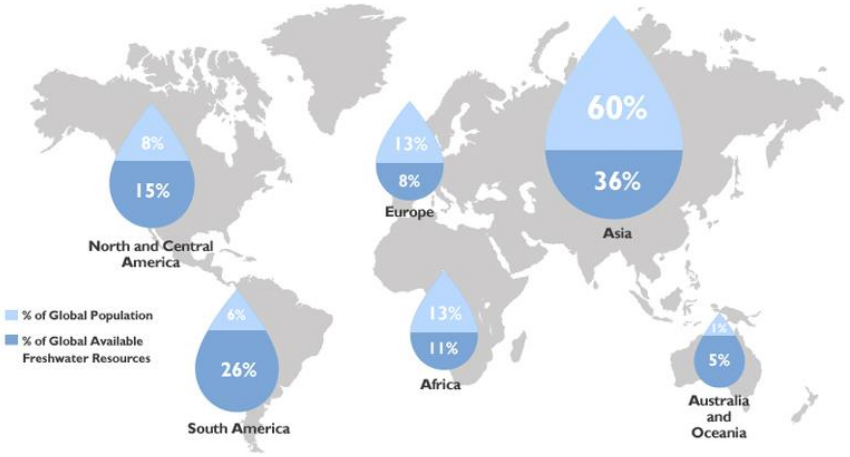


40% global population works in agriculture

FOOD SYSTEMS

Agriculture accounts for about 4% of GDP globally

The Cattle Site



WATER

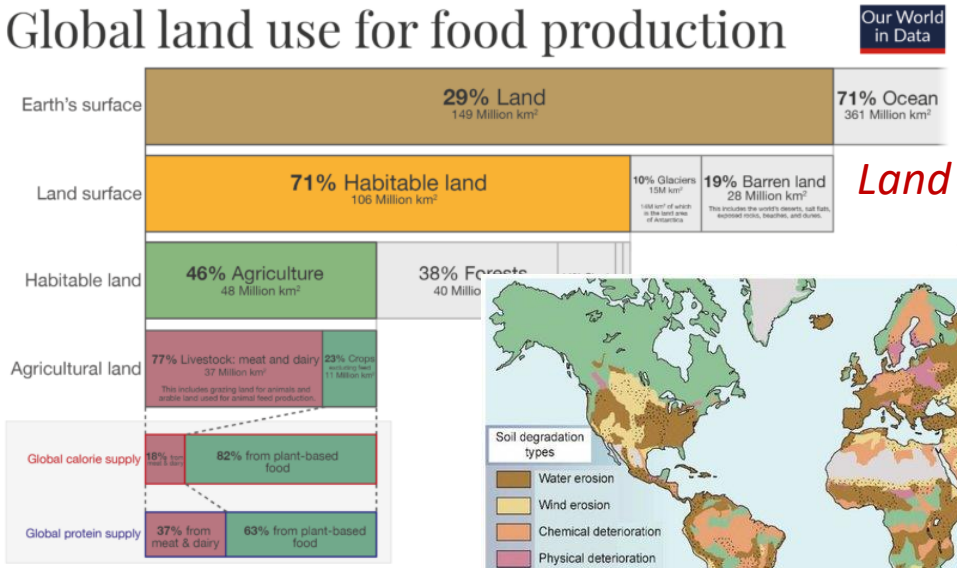
By 2025, an estimated 3 billion people will be living below the water stress threshold. Between 1995 to 2025, global population and per capita water consumption are projected to grow at a compound annual growth rate of 1.16 per cent and 0.67 per cent respectively.

Densely populated and developing regions of the world like Asia and Africa are expected to face the maximum water stress.

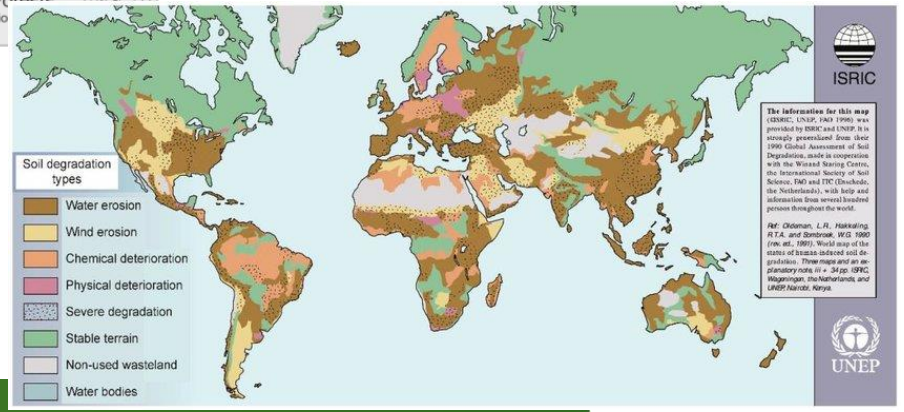
40% Population increase, reaching 9 billion by 2050

70% Of freshwater withdrawals made by agriculture

LAND



Land use & Land degradation



The importance of livestock

For PEOPLE

- Employment, income
- Economy
- Food and nutrition
- Cultural value
- Resilience and risk management

And the PLANET

- Biggest land user
- Natural resources:
  - ✓ Manure, soil carbon, energy…
  - - Water use/pollution, degradation, GHGe…

Opportunity cost!
e.g. carbon storage, food production, biodiversity, …

Spatial targeting
Land productivity ↗

Loss of flora and fauna

RUE
Restoration

Sustainability is a big issue and needs to be managed

Optimize the environmental footprint

↑ "Good" & "Bad" ↓

Without compromising the good!

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Sustainable food systems

1. **Sustainable agricultural production**

Sustainable intensification
Nature-based solutions
Agroecology
Regenerative agriculture
CSA

2. **Shift diets**

3. **Reduce waste**

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Sustainable food systems... and livestock production

1. **Sustainable agricultural production**
   - Stop expansion / conversion of natural ecosystems
   - Increase productivity
   - Resource use efficiency
   - Efficient meat and milk production
2. **Shift diets**
   - Less meat
   - No meat
   - Alternative meat
3. **Reduce waste**

Sustainable intensification
Nature-based solutions
Agroecology
Regenerative agriculture
CSA

LIVESTOCK-SPECIFIC SOLUTIONS

Dependent on:
Management & Location
Livestock production system

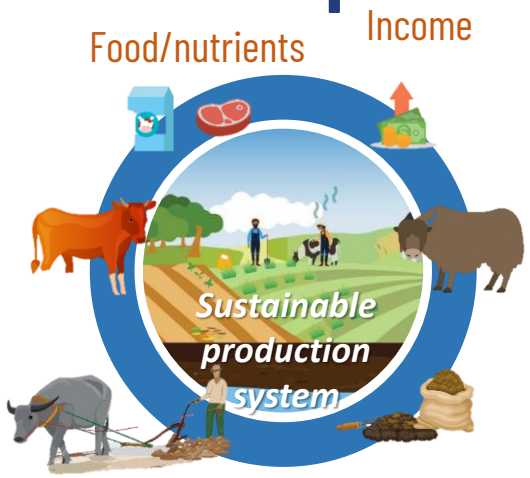
Livestock production systems

family farming

specialized livestock production systems

(AGRO-) PASTORAL SYSTEMS

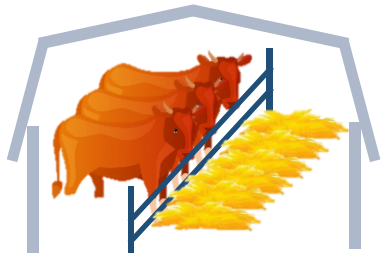
CO-EVOLVED AGRO-ECOSYSTEM



MIXED CROP-TREE-LIVESTOCK SYSTEMS

CIRCULARITY

Growing demand for livestock products



(SEMI-)SPECIALISED SYSTEMS

DECOUPLING OF LAND AND ANIMAL

- ✓ Low food-feed competition
  Biodiversity
  Carbon sequestration
- ✗ Overgrazing
  Low productivity
- ✓ Nutrient cycling and
  Use of by-products (non-food)
  Support crop production
- ✗ Low to medium productivity
  Limited carbon sequestration
- ✓ Efficient LS production
  Employment and income
- ✗ Ammonia emissions
  Manure run-off
  Pesticides, fertilizers, ...
  Food/feed competition

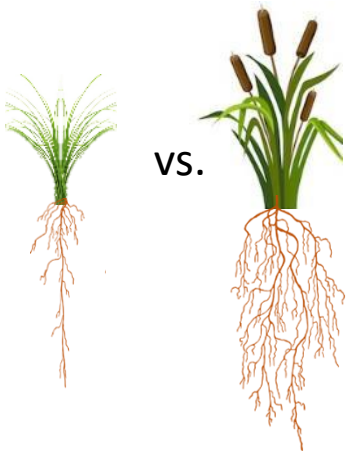
Ensuring system sustainability through integrating improved forages in mixed crop-tree-livestock systems in the tropics

Permanent grasslands

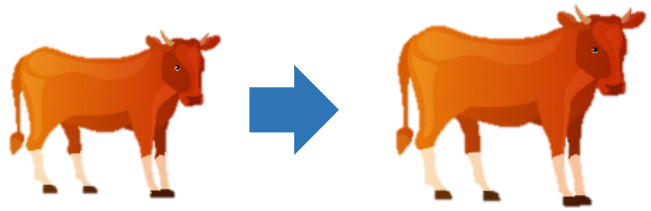
Cut and carry

The power of **Improved** forages

Highly productive



Better feed quality



But also adapted/tolerant to...

BIOTIC

Spittlebug pest

Rhizoctonia foliar blight

ABIOTIC

Soil acidity

Water scarcity

Water excess

MAIN TYPES OF FORAGES

- **Grasses:** Most widely used and commercialized i.e. >> 150 Million ha worldwide
  - ➢ Selection parameters: Biomass, forage quality, tolerance to biotic (pests and diseases) and abiotic stresses (scarcity and access of water)
  - ➢ Contribution to organic matter, favorable GHG balances and mitigating nitrate leaching and N2O emissions

- **Legumes**
  - ➢ High protein content
  - ➢ BNF and positive effect on GHG balances

- **Forage shrubs and trees** (also mainly legumes)
  - ➢ Nutrient cycling
  - ➢ Often high drought tolerance
  - ➢ Slow establishment but often long term persistence

Alliance germplasm (gene) bank: Conserving the world's largest collections of beans, cassava and tropical forages

≈38,000
Bean accessions

≈6,000
Cassava accessions

≈23,000
Tropical forage accessions

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

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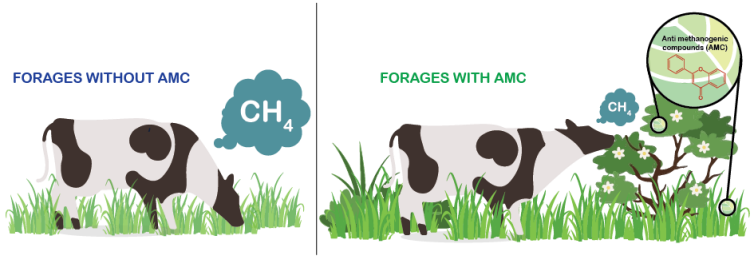
“improving” the forages

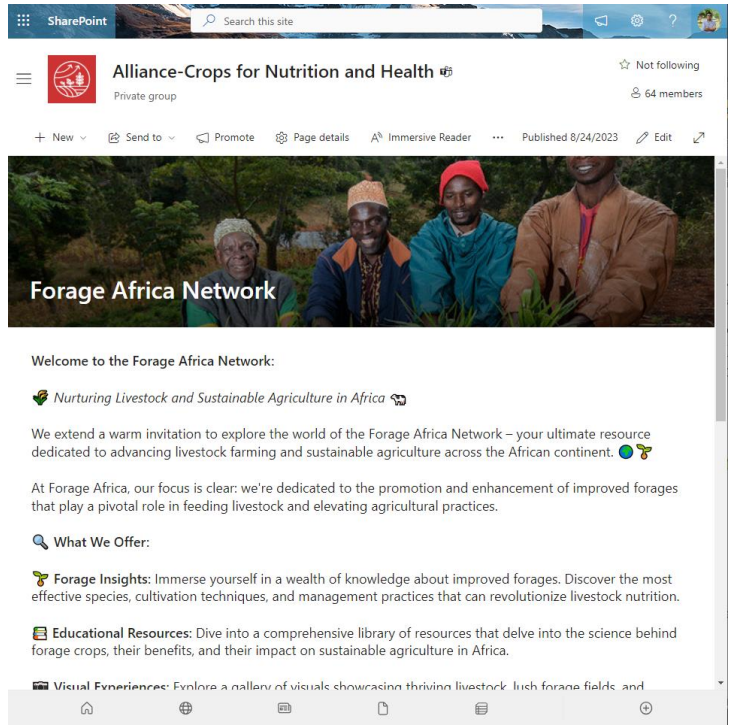
SELECTION & BREEDING

On-going activities:

Up-stream – screening of genebank for deep-rooted and AMC forages



Down-stream – FAN network



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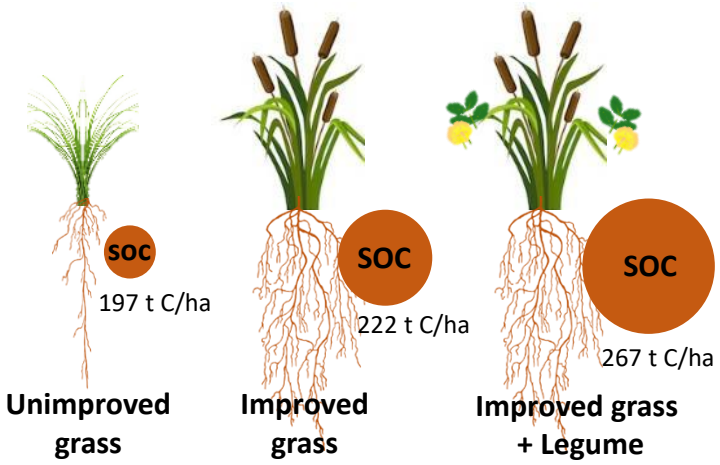
Ensuring system sustainability through integrating improved forages in mixed crop-tree-livestock systems in the tropics

Gaviria et al 2021. Fron. Vet. Sci.

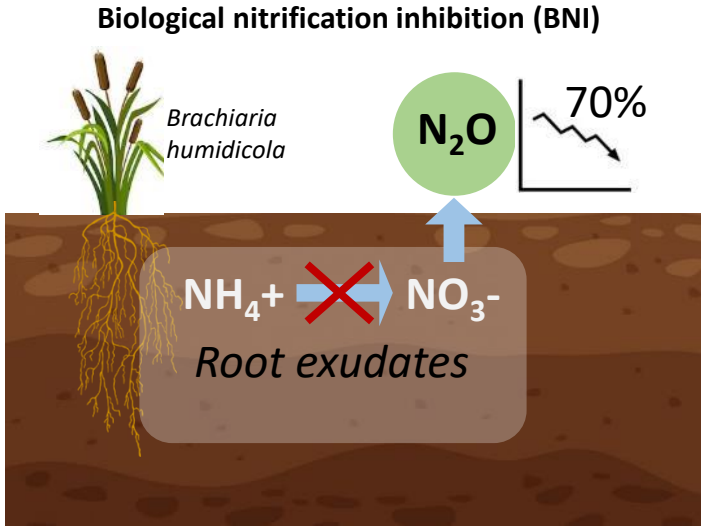
Sustainable intensification of **(improved) forage**-based systems, combining genetic, ecological and socio-economic intensification processes, increases the efficiency of the systems, has the potential to improve livelihoods, and yields a range of environmental co-benefits.

Carbon sequestration



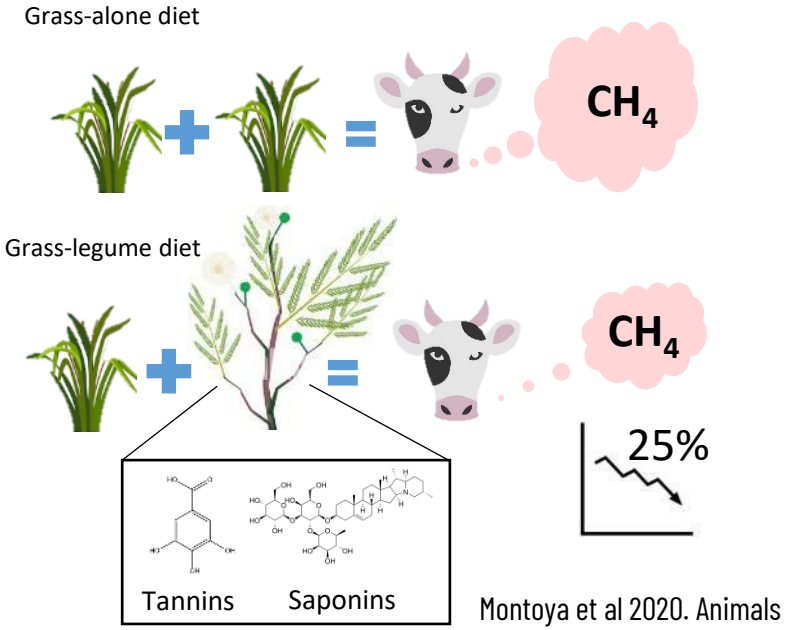
Fisher et al 1994. Letters to Nature

Mitigation of N_2O emissions



Subbarao et al 2009. PNAS

Mitigation of CH_4 emissions

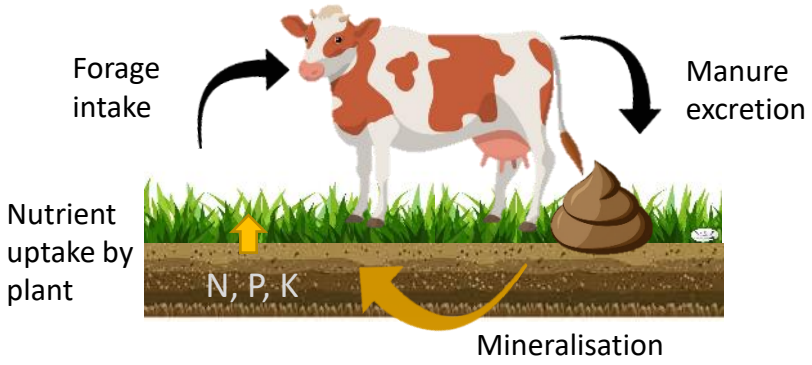


Montoya et al 2020. Animals

Contributions of improved cultivated forages to Agroecological transformation

1. Recycling

Use **local** renewable resources and resource cycles of nutrients and biomass

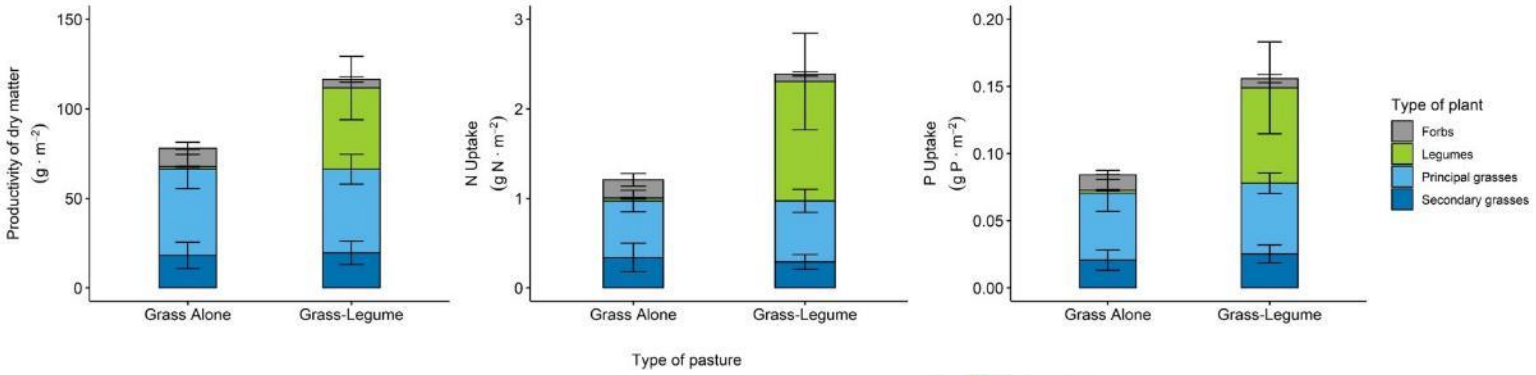


2. Input reduction

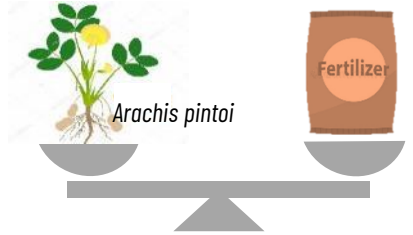
Villegas et al 2020. Diversity

Reduced need for **external** inputs (feeds, agro-chemicals and water)

Biological N fixation (BNF) of tropical forage legumes



- The integration of legumes increased pasture **biomass** production by about 74%
- N and P **uptake** were improved by two-fold.
- The legumes derived about 80% of their N via symbiotic N_2 **fixation**.



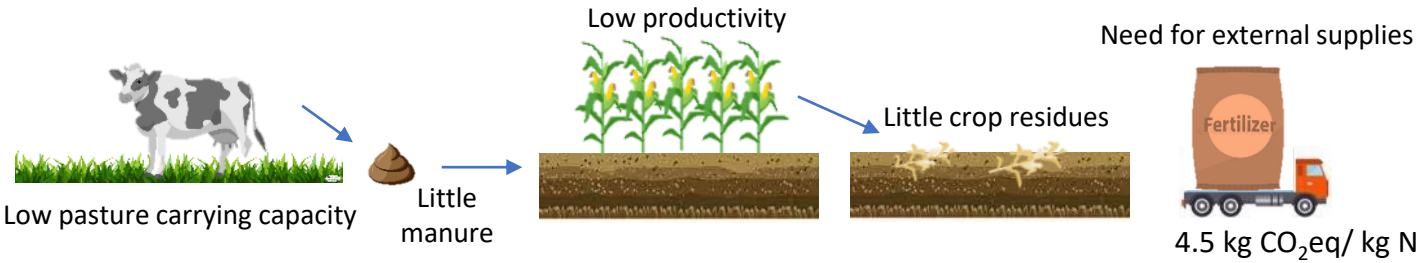
200 kg Urea/ ha/ yr

Gaviria et al 2020, Fron. Vet. Sci.

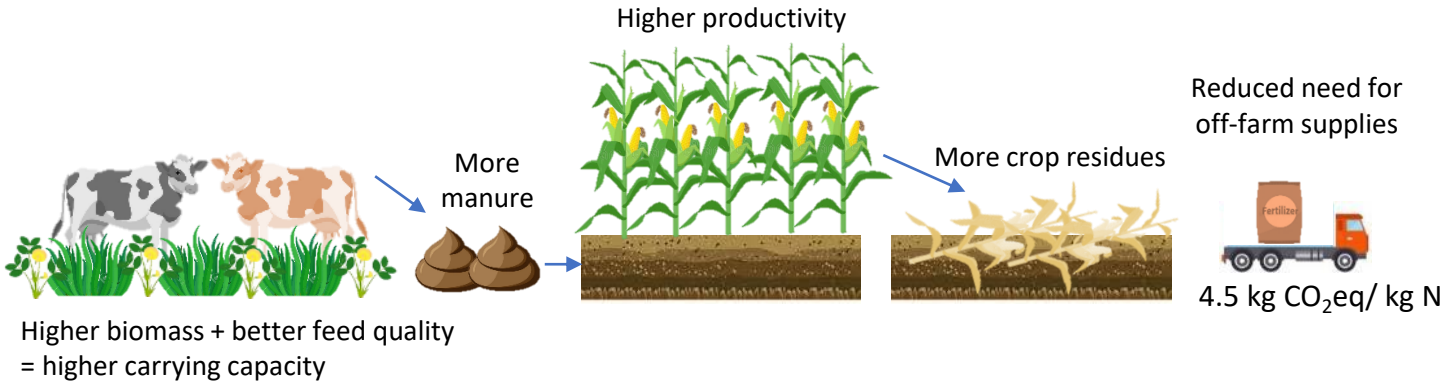
Contributions of improved cultivated forages to Agroecological transformation

2. Input reduction

Unimproved Grass-**alone** in crop-livestock systems



Improved grass + **legume** in crop-livestock systems



3. Animal health

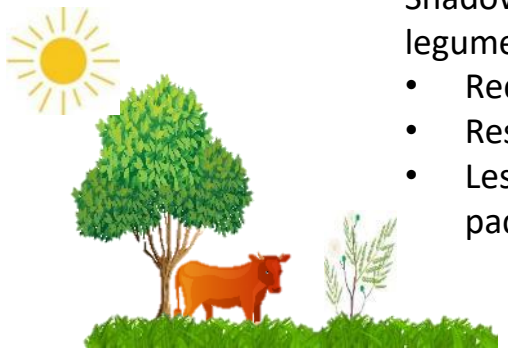
Improved animal nutrition

TABLE 1 | The nutritional value of five different diets based on tropical-forages (treatments) evaluated offered to Brahman cattle steers.

	Cay1	Cay2	CayLl*	CayLd**	Hay
DM	391	213	211	238	632
CP, g kg DM^{-1}	44.5	83.3	96.2	128.5	62.3
NDF, g kg DM^{-1}	709.8	682.2	638.5	580.9	612.6
ADF, g kg DM^{-1}	414.2	349.1	359.2	299.3	388.9
Ash, g kg DM^{-1}	118.3	121.4	124.5	175.6	140.3
GE, Mj kg DM^{-1}	16.2	17.2	16.7	17.5	14.1
IVDMD, g kg^{-1}	511	618	610	606	479

Higher protein, digestibility and energy in grass-legume diets

Animal welfare



Shadow provided by trees or shrub legumes in **silvopastoral** systems

- Reduced heat stress/ water loss
- Rest areas
- Less walking around the paddock = energy loss

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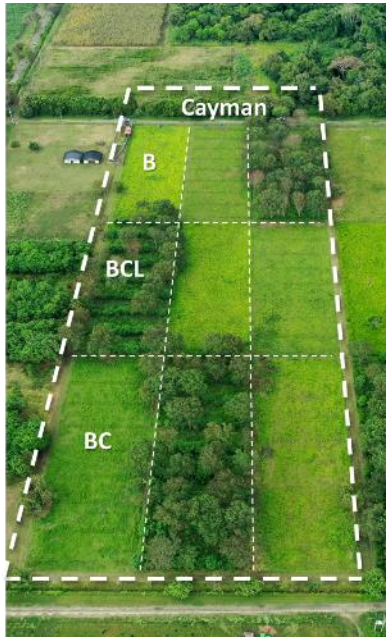
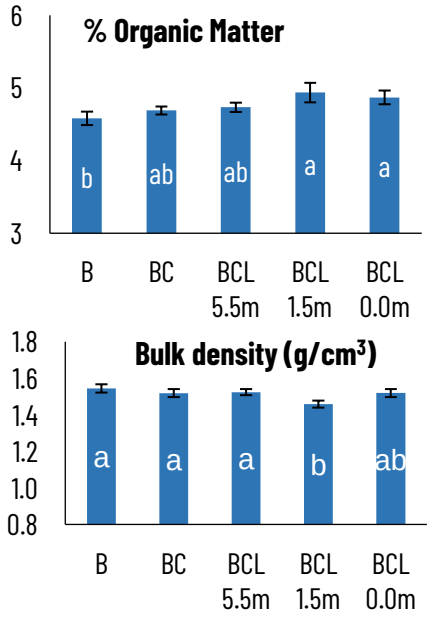
Vazquez et al 2020. AGEE

Contributions of improved cultivated forages and silvopastoral systems to Agroecological transformation

4. Soil health

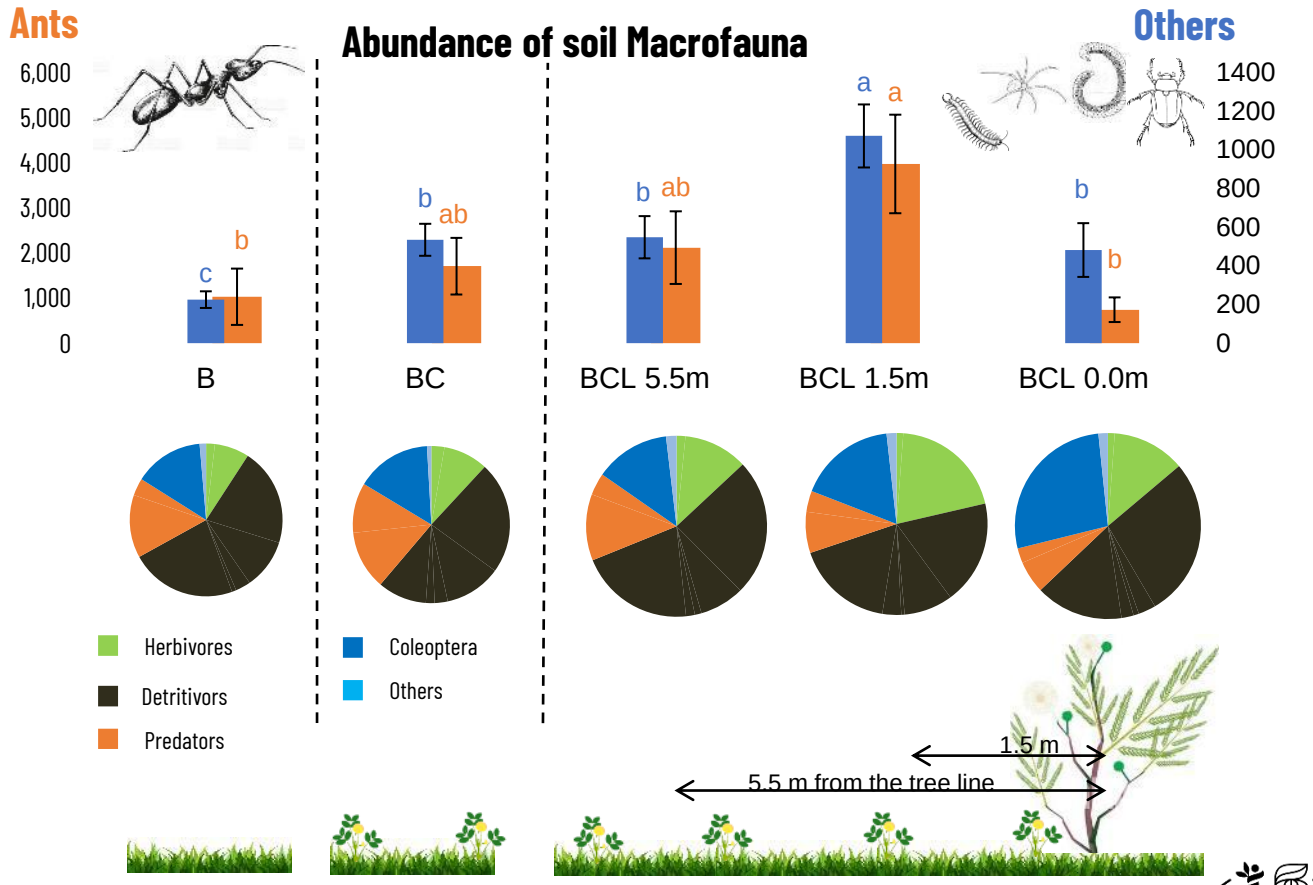
B = *Brachiaria* grass-alone pasture
BC = *Brachiaria* + *Canavalia* herbaceous legume
BCL = *Brachiaria* + *Canavalia* + *Leucaena* tree legume





Biogenic Aggregate

5. Biodiversity



Contributions of improved cultivated forages to Agroecological transformation

Charry et al 2016. Tropentag

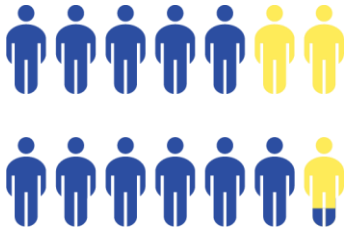
7. Economic diversification

Crop-tree-livestock systems

- Increased animal productivity (weight gain)
- Cattle (=savings)
- Timber
- Fruits
- Payment for ecosystem services
  - C sequestration
  - Water quality
  - Shadow
  - Biodiversity (insects, pollinators, birds)
- Ecotourism (bird watching)

9. Social values & diets

Animal source foods for human nutrition

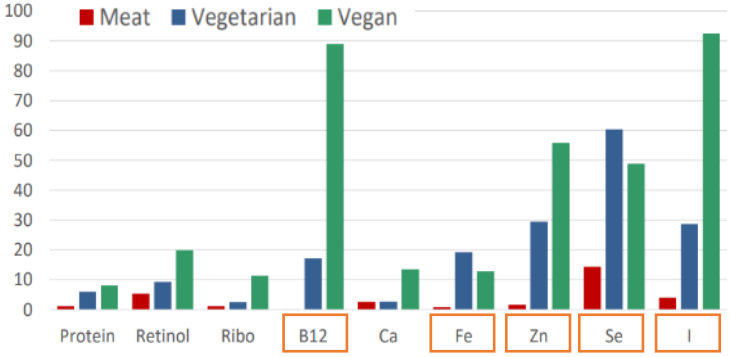


2 billion people suffer malnutrition for micronutrients

800 million suffer caloric defficiencies

Global Nutrition Report, 2016

% of inadequate intake of nutrients in meat consumers, vegetarians, and vegans.



EPIC Study UK (n=≈24.000; Sobiecki 2016)

10. Fairness

Economic indicators improved in mixed pastures

Evaluated technologies	Grass-alone	Grass+legume
Net income system (US$ ha^{-1} y^{-1})	356	695
NPV (US$)	(473)-(288)	1,716-2,055
Prob NPV<0 (%)	72	0
IRR (%)	10-11	21-22
Payback period (years)	6	4
B/C ratio	0.96-0.98	1.12-1.13
Minimum area required to have a profitable system (ha)	6.54	3.76

Enciso et al 2019. TGFT

Consumers are willing to pay **price premiums** for "eco-friendly" and "animal welfare compliance" labels in the city of Cali, Colombia.

Table 1 WTP for "eco-friendly" and "animal welfare compliance" labeled beef

Label	No information	With information
Eco-friendly	$ 0.74	$ 1.18
Animal Welfare	$ 0.83	$ 0.84

⋆ Average WTP for conventional beef in samples: USD $4.73/lb
⋆⋆ Prices in USD/lb of meat (USD/COP XRT 08/22/2016)

Further reading

frontiers in Sustainable Food Systems

REVIEW
published: 11 November 2021
doi: 10.3389/fsufs.2021.742842

Tapping Into the Environmental Co-benefits of Improved Tropical Forages for an Agroecological Transformation of Livestock Production Systems

An M. O. Notenbaert[1], Sabine Douxchamps[2], Daniel M. Villegas[3], Jacobo Arango[3], Birthe K. Paul[1], Stefan Burkart[3], Idupulapati Rao[3], Chris J. Kettle[4,5], Thomas Rudel[6], Eduardo Vázquez[7], Nikola Teutscherova[8], Ngonidzashe Chirinda[9], Jeroen C. J. Groot[10], Michael Wironen[11], Mirjam Pulleman[3], Mounir Louhaichi[12], Sawsan Hassan[13], Astrid Oberson[5], Sylvia S. Nyawira[1], Cesar S. Pinares-Patino[14] and Michael Peters[1]*

OPEN ACCESS

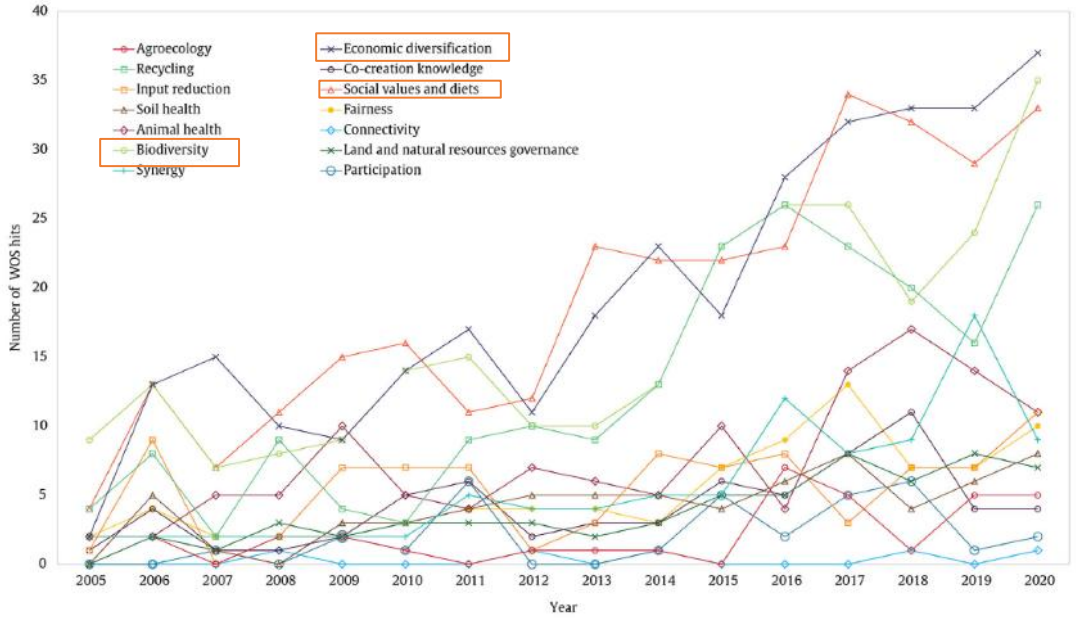


FIGURE 3 | Evolution of the interest of the scientific community for the different nexi between forages and principles.

Notenbaert AMO, Douxchamps S, Villegas DM, Arango J, Paul BK, Burkart S, [...] Peters M (2021) Tapping Into the Environmental Co-benefits of Improved Tropical Forages for an Agroecological Transformation of Livestock Production Systems. *Front. Sustain. Food Syst.* 5:742842. doi: 10.3389/fsufs.2021.742842

Outlook

There is increased research interest and understanding of the **agroecological** dynamics related to improved forages and their integration in mixed crop-tree-livestock systems.

NEXT STEPS:

Forage varieties tolerant to a wide range of biotic and abiotic stress factors

- Boosted by state-of-the-art genomics and phenomics

Increased understanding of multiple interacting impacts of improved forages at the food system level

- Quantification of agro-environmental trade-offs and synergies
- Understand drivers of uptake of improved forages, especially within agroecological initiatives, is needed for guiding large-scale investments and supporting the decision-making processes around that.

Influential communication targeting policymakers and the different publics

- Raising awareness at different decision-making levels should aim to differentiate, label and promote livestock products derived from agroecosystems based on agroecological principles

Thanks!

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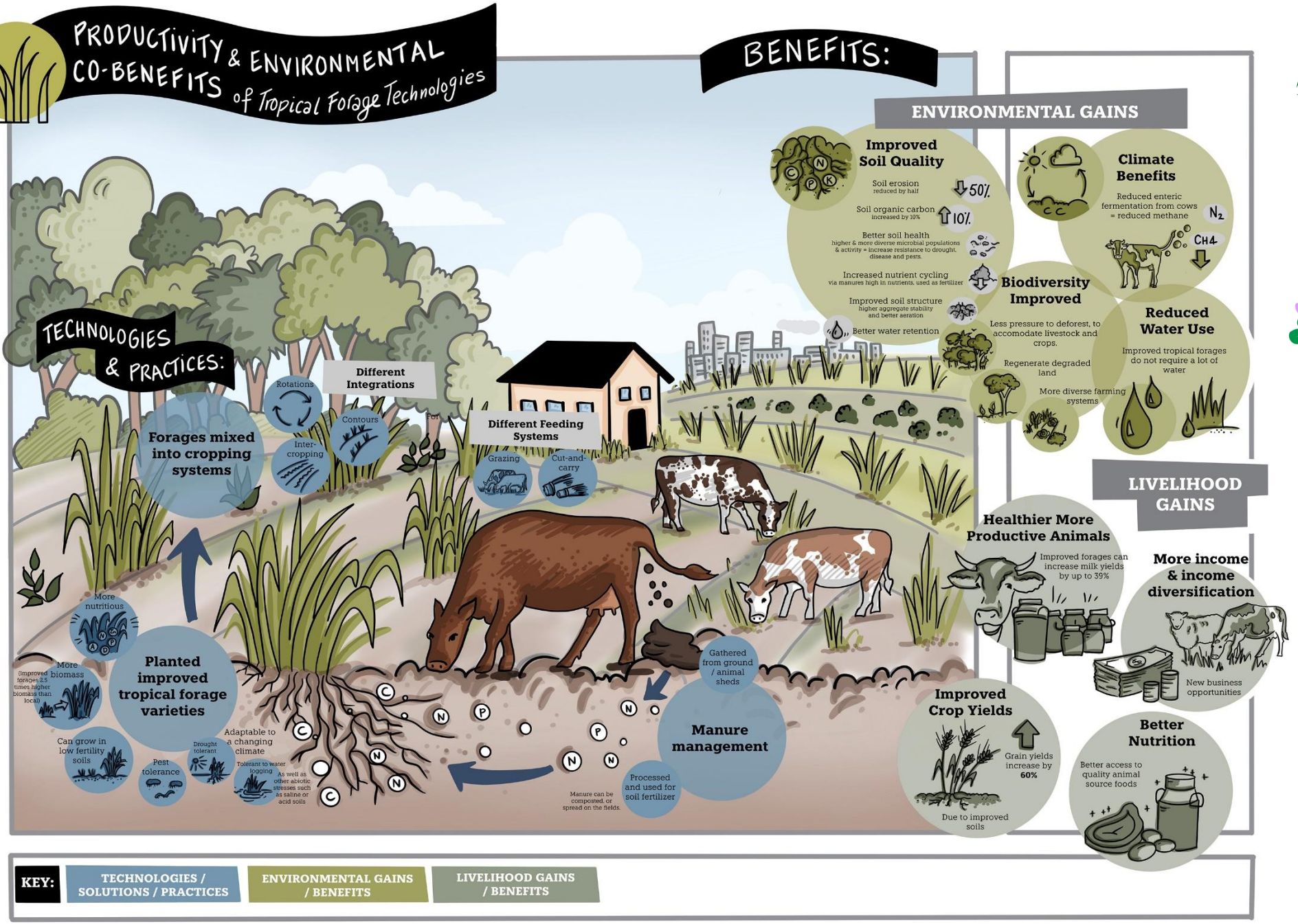
We thank all donors that globally support our work through their contributions to the CGIAR system.



Grasses

Most used/ commercialized

> 150 Mil ha worldwide

Legumes

High protein content

Biological Nitrogen Fixation

Shrubs and trees

Also mainly legumes

Often high drought tolerance

Slow establishment

Long-term persistence

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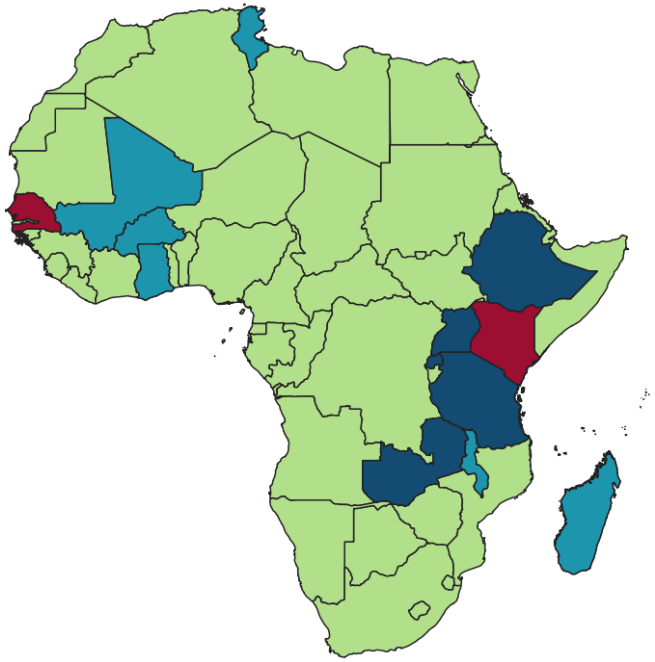
Our research focus

- Forage selection and breeding (focus on Africa = fairly new)
- Integration in farms and landscapes
  - Local adaptation and agronomic practices
  - Crop-Livestock-Tree interactions, circularity
  - Grass-legume mixes, forage-restoration nexus
  - Spatial targeting
- Quantification of multi-functional benefits:
  - Yield and animal performance
  - GHGe intensity, water use efficiency, soil health
  - SOC sequestration (incl. deep-rooting)
  - Economic feasibility
  - Gender
  - Resilience
- Scaling approaches:
  - Business models, blended learning, blended finance, …
  - Seed systems!!!



Research partners:
- One CGIAR
- NARS
- Universities