# Sustainable landuse, soil and integrated farming systems management

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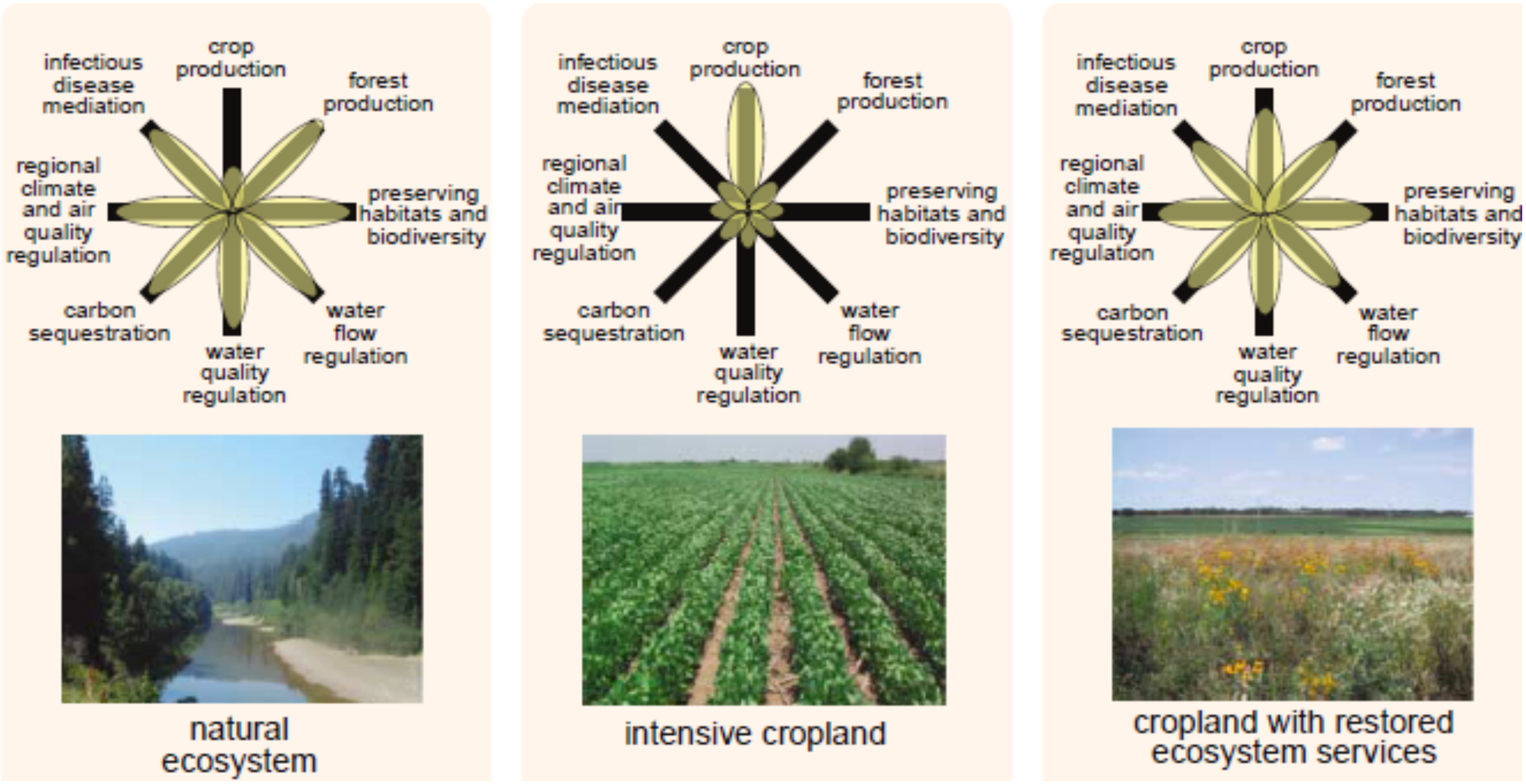
# Land-use and trade-offs of ecosystem services




Source: J.A. Foley et al., (2005) Science, 309, 570

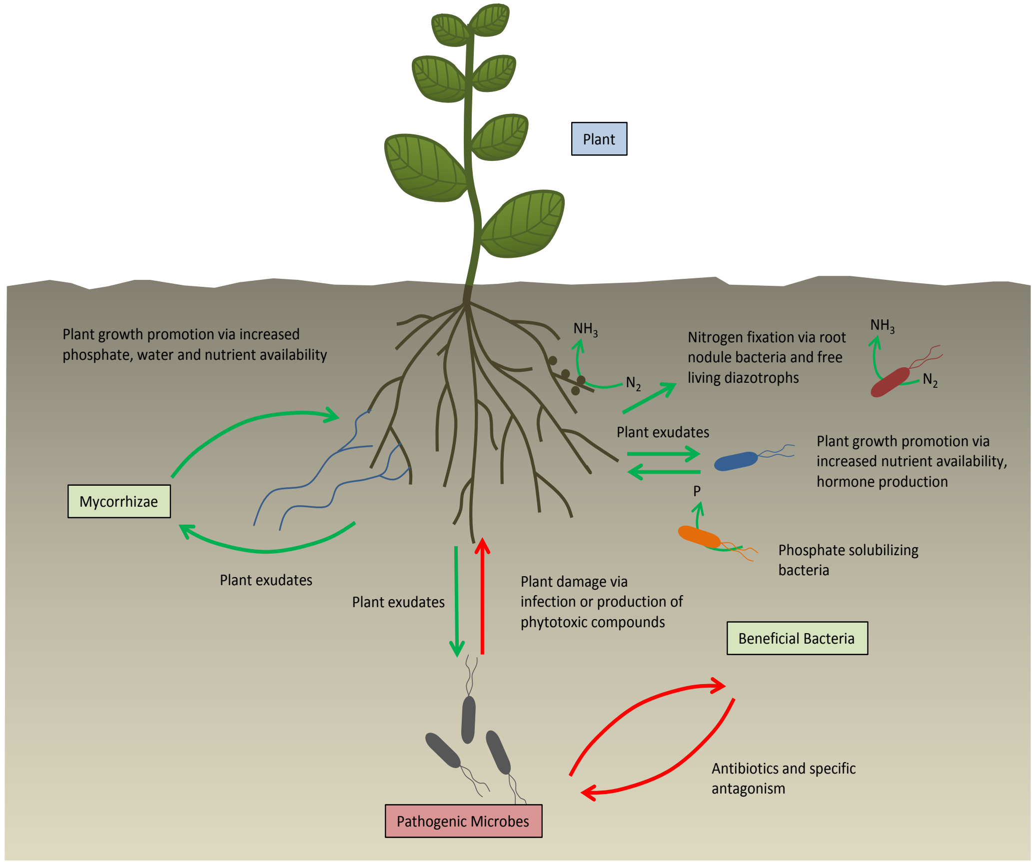
# Ecologically intensive agriculture = Agroecology: A new paradigm?

- Maximising the biomass production.
- Optimising functional biodiversity.
- Supporting biogeochemical cycles.
- Anticipating the social, economic and political implications.

Role of soil microorganisms?

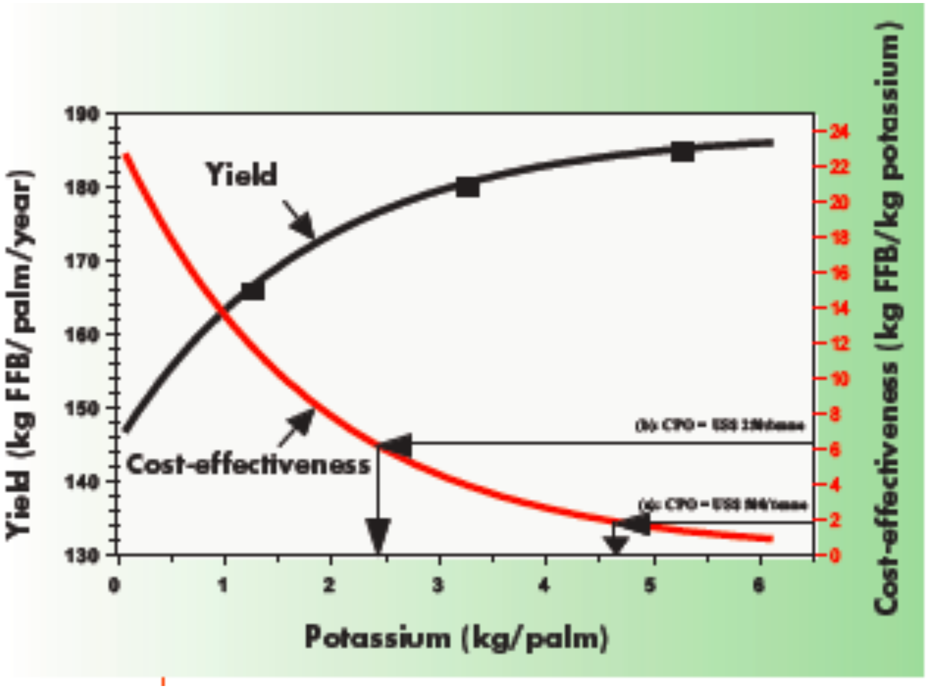
# Relevance of using microbial biotechnologies in Asian Agriculture:

- Low sustainability of tropical soils (low fertility and limited availability of nutrients),
- Mono-cropping increasing soil erosion,
- Massive application of polluting pesticides and mineral fertilizers




- There is needs for restoring degraded soils by an enhancement of soil biodiversity/soil health,
- Promotion of agro-ecology (no/low tillage, low or null inputs agriculture, intercropping legumes-crops, agroforestry…)
- Utilization of beneficial microbial products

# Economical impact of the mineral fertilization of perennial plantations




## Options to sustain the production at a lower cost

* Cover crops at the early stage of the plantations
* Recycling of the remaining products
* Potential of the biofertilisers for partially taking the mineral fertilisers over

# Roles played by the native soil microbial communities

## Native Soil Microbial Communities = Black box

**We have to investigate!**

Example of the Laetitia's PhD entitled «The role of the soil microbial communities in sustainable rubber tree cultivation in North-Eastern Thailand »

# Example of the rubber plantations in Thailand

- **Chronosequence**: 9 plantations of different ages in Ban Don Chang

  - 3 « Young » plantations: 3 years old
  - 3 « Medium » plantations: 6 years old
  - 3 « Old » plantations: 16 years old

  + 3 Fields of Cassava (no rubber tree history)

  → Similar management practices: absence of cover crops, similar fertilization rates, reduced soil type variation (area of less than 2 $km^2$)…

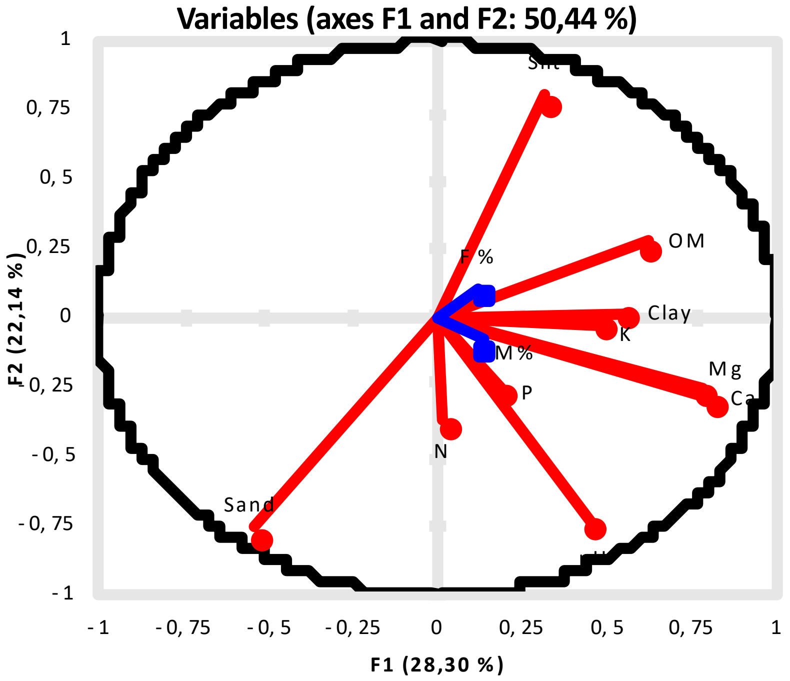
# Example of the rubber plantations in Thailand

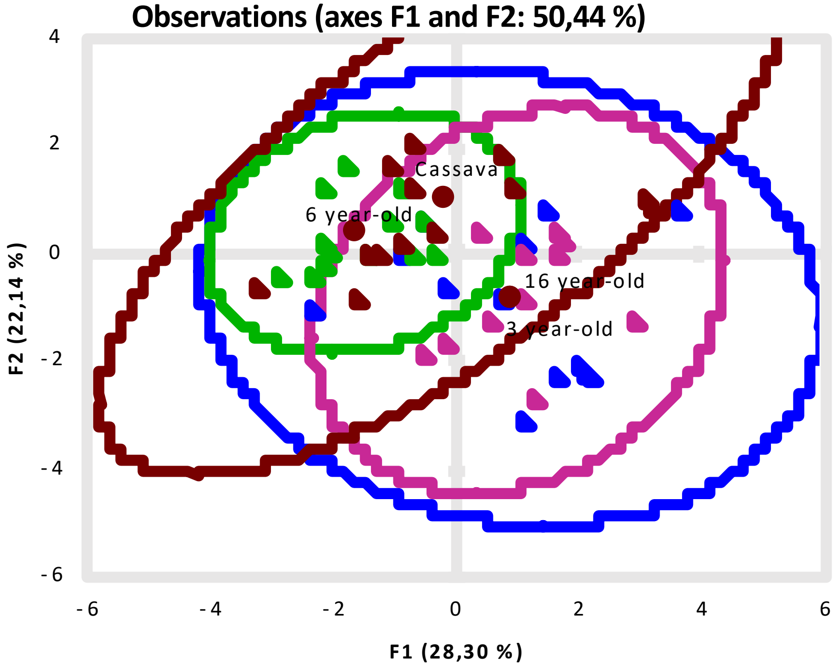
- **AMF communities in roots**:

Herrmann et al. 2016, Archives of Agronomy and Soil Science

→ Intensity of colonization (root staining):

- Very high colonization in all sites (>73%)
- Intensity not affected by the species, the age of the plantations, or the soil characteristics

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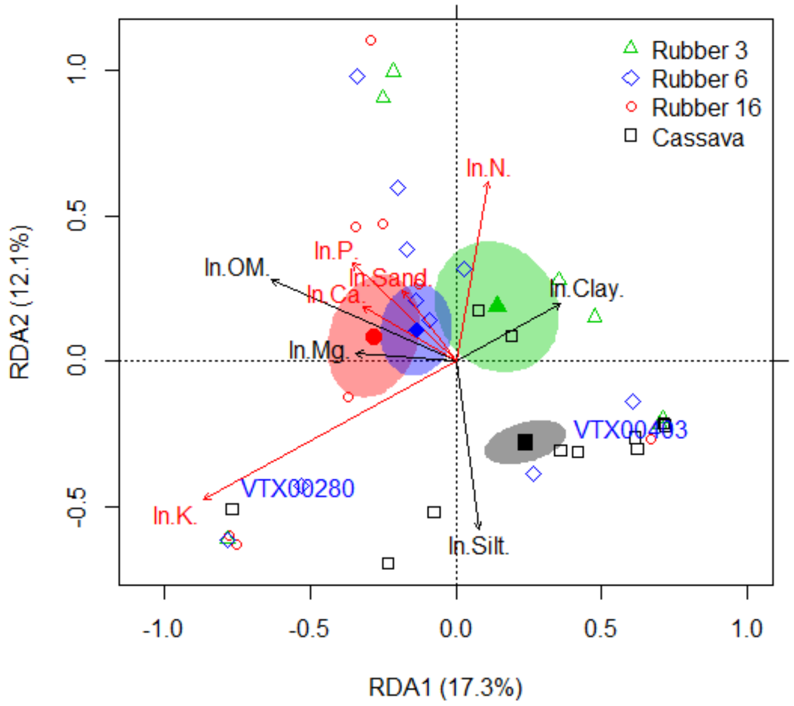
# Example of the rubber plantations in Thailand

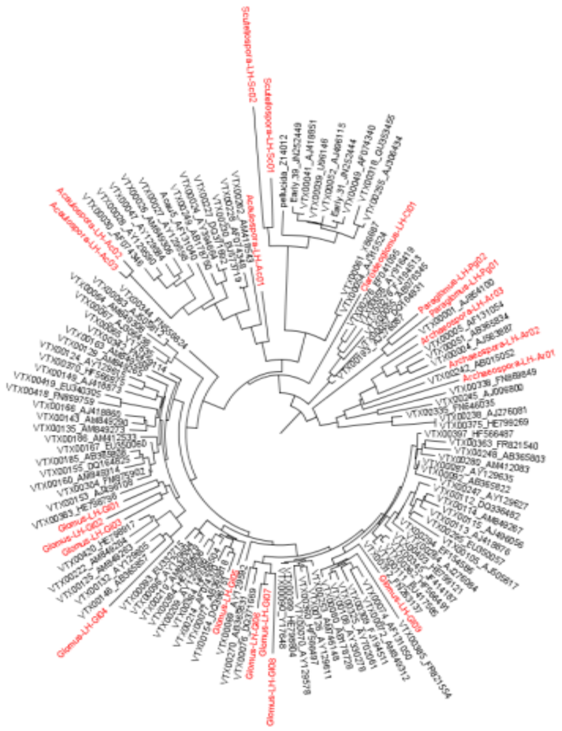
Herrmann et al. 2016, Mycorrhiza 26, 863-877

- **AMF communities in roots**:

→ 454 sequencing:

- Identification of new Virtual Taxa (VT)
- High diversity : 111 VT in total



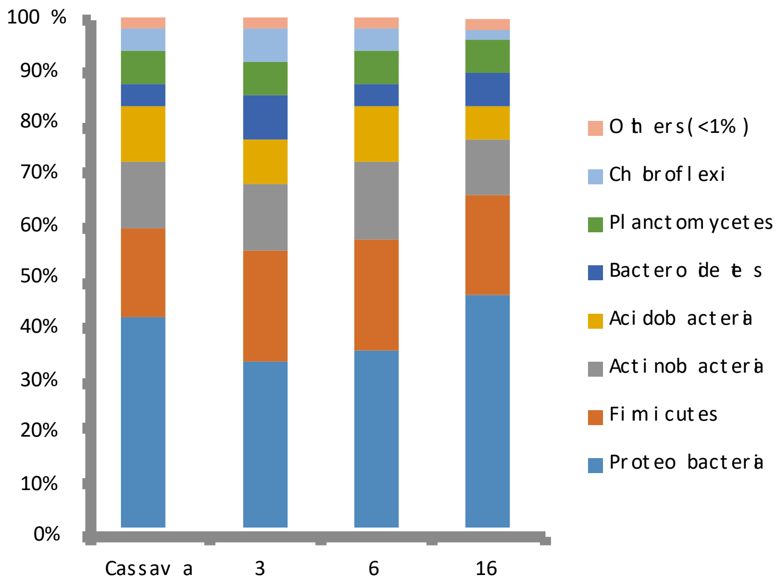
- Strong separation of cassava and rubber AMF communities
- Gradual shift with time from young to old plantations

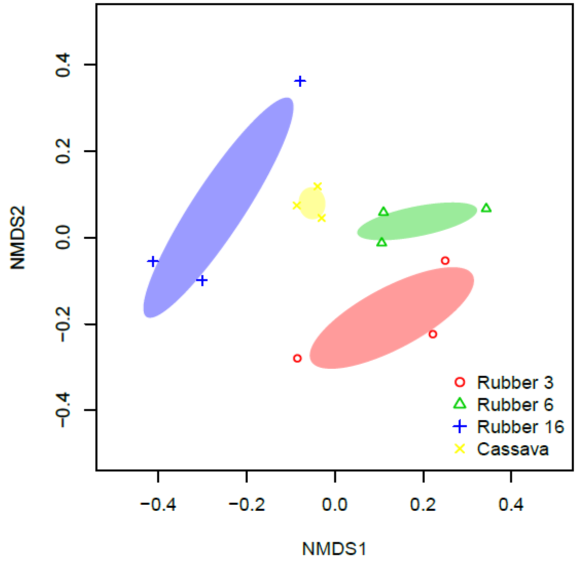
# Example of the rubber plantations in Thailand

- **Total bacterial and fungal communities in soils:**

Herrmann et al. Sciences for the total Environment (submitted)

→ 454 sequencing



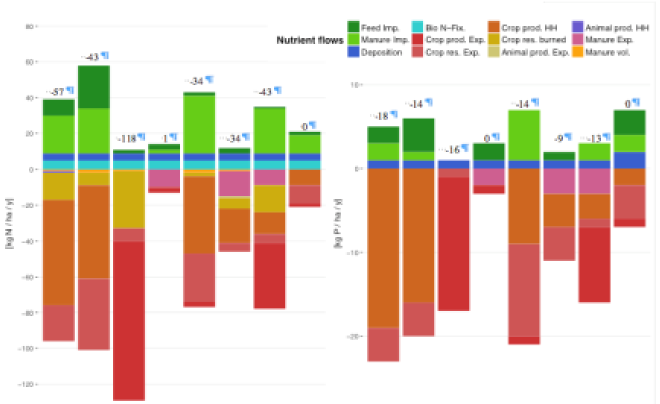



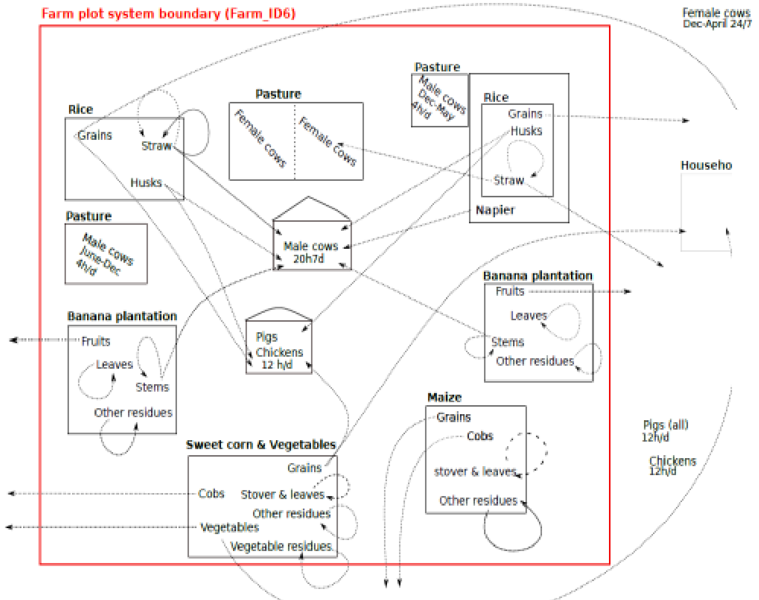

Non-metric multi-dimensional scaling (NMDS) plots displaying the bacterial communities (OTU level) associated to the roots of rubber tree or cassava.
Ellipses indicate one standard deviation around the centroid position of each site group.

Composition of the bacterial community at the phyla level in the different site types.
Within each bacterial phyla, means accompanied by the same letter do not differ significantly at P ≤ 0.05 (pairwise comparisons using the Tukey (HSD) test.
Pairwise comparisons of the bacterial class means using the Tukey (HSD) test did not show any significant difference at P ≤ 0.05

# Research topics around mixed farming systems – biophysical studies

## N and P cycling efficiency



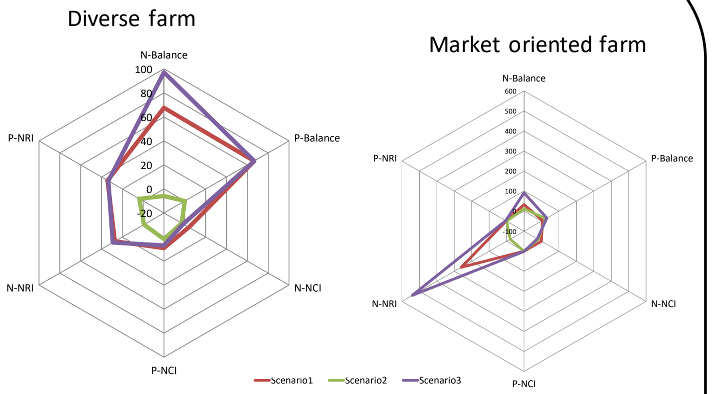

→ identification of efficient nutrient management options at farm level for different farm types

## Water productivity

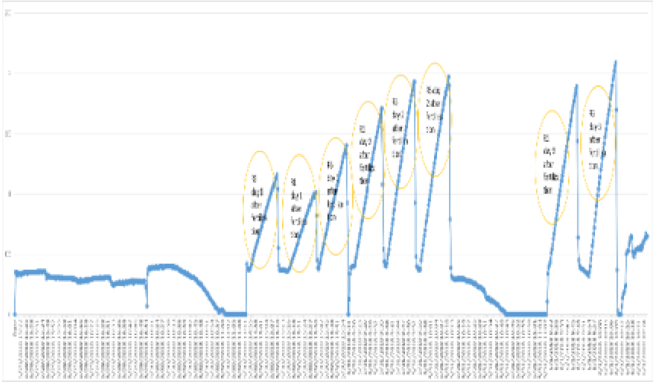
LWF = WFfeed + WFdrink + WFserv

WFfeed = [∑(Qfeed * WFingr) + WFcooking + WFmixing] / Pop

→ identification of water saving options




## GHG emissions



→ identification of GHG mitigation options

# Regional platform of forage legumes

In December 2017, representatives from eight Asian countries met in Haikou, China, to discuss about sustainable diversification in tropical crop-livestock systems through biological nitrogen fixation (BNF) by forage legumes. The workshop resulted in the creation of a network of institutions and individuals committed to increase the multiple benefits of BNF, along with a roadmap detailing initiatives to fulfill identified research and development gaps.

## Asian Forage Legumes Platform

### Background

Often described as lacking diversity and needing to improve sustainability, crop-livestock systems, the most important farming systems in tropical Asia, are increasingly under demographic and climatic change pressures. In order to address such challenges, soil fertility and biomass management must quickly become more efficient.

The integration of multipurpose legumes in crop-livestock systems offers several advantages. When used as green manure, multipurpose legumes contribute to mitigation of soil erosion by providing a better soil cover. Through symbiotic nitrogen (N) fixation, the legumes fix atmospheric N and a part of this N is released into the soil and provides benefits to the intercropped crop. In addition to nitrogen, intercropped legumes can also significantly contribute to enhancing soil carbon content through the leaves and root systems remaining in the field after harvest. This shows the triple advantage of intercropping crops with legumes and the positive impacts it has on soil health and soil fertility. When legumes are used as forages, they increase the quality and quantity of livestock feed, therefore helping increase livestock production and household food security. Efficient manure management allows a return of nutrient to the soil, therefore increasing soil fertility and health.

Symbiotic $N_2$ fixation is a natural process of extreme importance in world agriculture. The most important $N_2$-fixing agents in agricultural systems are the symbiotic associations between crop and forage legumes and rhizobia. Annual inputs of fixed N are calculated to be 2.95 Tg for the pulses and 18.5 Tg for the oilseed legumes. The positive interactions between $N_2$-fixing forage legumes and non-$N_2$ fixing plant species often contribute to a significantly larger extent to mixing effects in biomass yield than the interactions between other functional groups.

Efforts to mainstream forage legume and rhizobia use in the region have been scattered. It is now essential to take stock on past efforts and develop a road map on how to increase $N_2$ fixation in crop-livestock systems in tropical Asia.


## Objectives of the Platform

The Asian Forage Legumes Platform aims to increase the level of knowledge on biological nitrogen fixation or BNF in Asia, with a view to facilitating increased benefits from BNF of farming systems in Asia, by:

- facilitating **collaboration** among network members on **research projects**;
- fostering **communication** around **successful integration** of forwages legumes in the region; and
- **sharing** forage germplasms, rhizobia strains and methods of evaluation.

## Roadmap

Four major interconnected initiatives will be pursued by the Platform, looking at the integration of forage legumes into crop-livestock systems at four levels: landscape, farm, soil-plant, and microbe.

**Project 1** Environmental aspects and abiotic stresses

Identification and conservation of stress-tolerant (salt, drought, water logging, low and high pH) forage legumes species and their corresponding geographical areas in tropical and sub-tropical Asia

**Project 2** Forage legume agronomy

Match-making between forage legume germplasms and innovative intercropping systems, and evaluation of multiple benefits at farming system level

**Project 3** BNF benefits

Quantification of BNF by forage legume in the field and assessment of the status of fixed nitrogen in the soil-plant system using isotopic techniques

**Project 4** Microbiology

Establishment of a bank of rhizobia for forage legumes, testing of selected commercial inoculants, and establishment of quality control guidelines to ensure high quality of inoculants

Chinese Academy of Tropical Agricultural Sciences (CATAS)
Haikou, China
**Host**

International Center for Tropical Agriculture (CIAT)
Hanoi, Vietnam
**Convenor**

**Advisor/s**

University of Deakin, Melbourne, Australia
Queensland University of Technology, Brisbane, Australia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**Members**

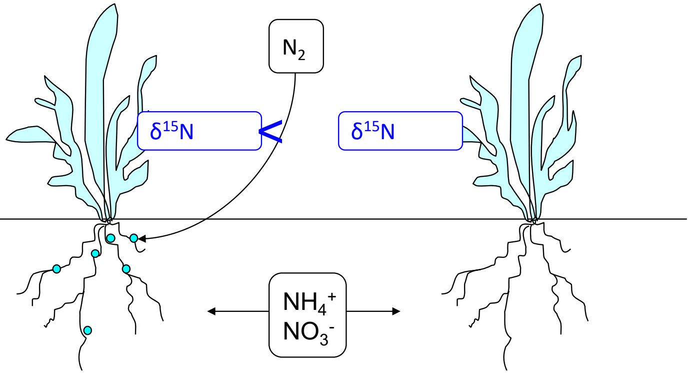
| | |
|---|---|
| Bangladesh | Soil Resources Development Institute<br>Khulna University |
| Cambodia | University of Battambang |
| India | Indian Council of Agricultural Research |
| Laos | National Agriculture and Forestry Research Institute |
| Myanmar | Yezin Agricultural University<br>Ministry of Agriculture, Livestock and Irrigation |
| Philippines | Philippine Carabao Center |
| Vietnam | Northern Mountainous Agriculture and Forestry Science Institute<br>Vietnam National University of Agriculture |

# Integration of *Canavalia brasiliensis* into a hillside crop-livestock system: environmental adaptation and nitrogen dynamics

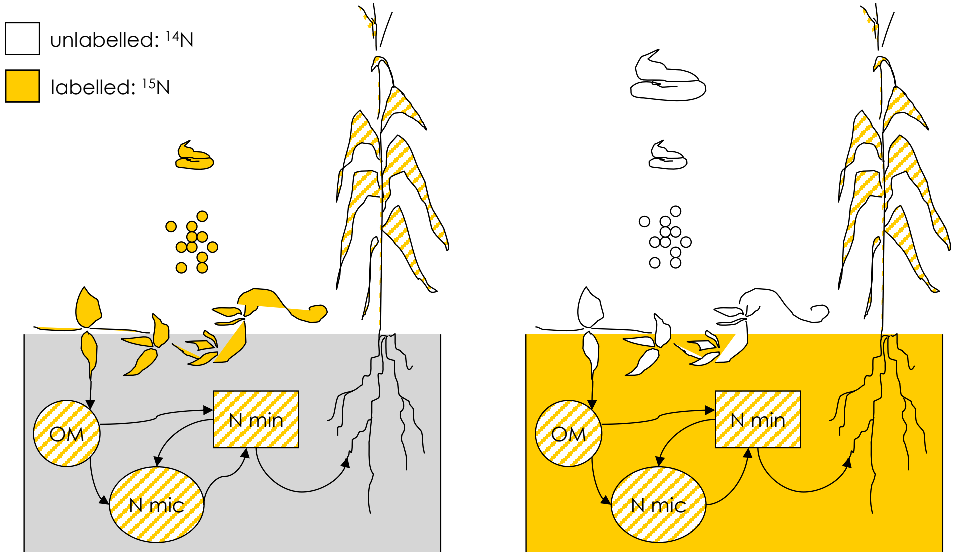
## Assessment of net N input into the system: N budgets and fertilizer value, using isotope techniques

N balance [kg N $ha^{-1}$] = (N fert + N seed + N fix) – (N export)

$^{15}$N natural abundance method

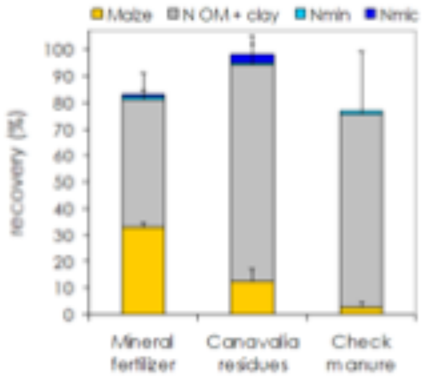



$$\% \text{ Ndfa} = \frac{\delta^{15}N_{non\text{-}fixing} - \delta^{15}N_{fixing}}{\delta^{15}N_{non\text{-}fixing} - \delta^{15}N_{fixing\ bnf\ only}}$$




**DLT** – direct labeling technique

**ILT** – indirect labeling technique





Douxchamps et al. (2010) Nutrient Cycling in Agroecosystems, 88: 447-462

Douxchamps et al. (2011) Plant and Soil, 341: 179-192

# Harnessing microbial biotech tools for sustainable agricultural systems & landscapes: Common Microbial Biotechnology Platform (CMBP) in Hanoi



CMBP
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# Three programmatic areas of CMBP:

1. *Quality Control approach:* Technical quality assurance for commercial microbial products such as the ones manufactured by AGI through ATQ (Agricultural Technology Quality Limited Company). The CMBP will establish quality control processes and train AGI staff for enabling the Institute to undertake this as its long-term function.

1. *Formulation of rhizobial and mycorrhizal inoculants* – Enhancing AGI staff and students' capacity, as well as the Institute's physical facilities, in the fields of biological materials, soil inoculants and soil microbiology. The CMBP will likewise facilitate opportunities for expanding the range of products and derivative formulations in the routine testing cycle.

1. *Microbial biotechnology methodologies for assessing the role of microorganisms in the sustainability of cultivated soils* - Developing biotechnology methodologies for assessing microbial communities playing a key role in N, P and C cycles and also identification of microbial parameters as soil indicators.

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# Research, Training and Publication at CMBP:

CMBP
Common Microbial Biotechnology Platform

*Little guys, big role*

Understanding how **MICROORGANISMS** sustain health and productivity of the **SOIL**

and how **YOU** could benefit from it

Soils provide the foundation to the agriculture system. Agriculture is only as productive, efficient, and healthy as the soils which nurture and sustain it.

Healthy and fertile soils are able to support and sustain plant growth by making key nutrients and micro-elements available for use by the plant.

How do you know whether the soil of your farm or plantation is nurturing nutrients and micro-elements essential for plant growth? How confident are you about the sustainability of your soil fertility management?

## Should you get in touch with the CMBP?

YES, if you –

- Are a researcher interested in the study of microbial biotechnology.
- Are engaged in the agriculture business and are concerned about the overall, long-term sustainability of the yields; would like to know the status of your soil health and quality; and are interested to benefit from the interactions between soil microbial communities and crops in order to increase production at the lowest environmental cost.
- Work with legumes and other crops and have a stake in optimal, sustainable legume yields. The CMBP promotes biological nitrogen fixation, and works towards development of effective plant growth-promoting rhizobacteria (PGPR), including rhizobial, inoculants.
- Are engaged in the fertilizer manufacturing business and are interested in the development of new microbial inoculants effective for plant growth, in order to serve a huge market, particularly, in Southeast Asia.

## Get in touch with:


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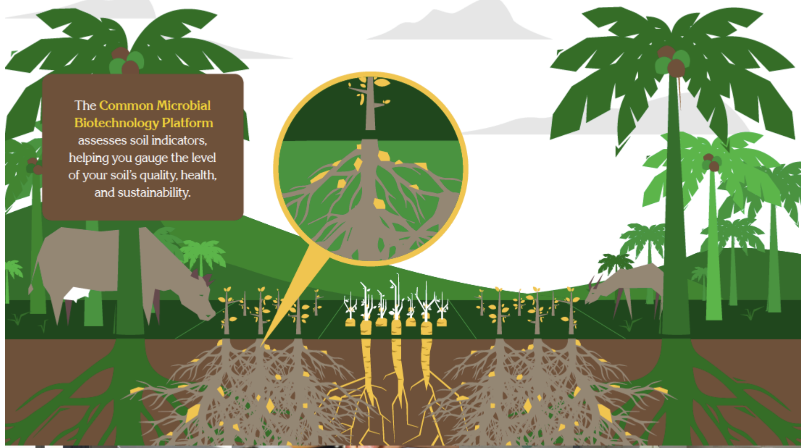


The Common Microbial Biotechnology Platform (CMBP), a partnership between the Vietnam Agricultural Genetics Institute (AGI), the International Center for Tropical Agriculture (CIAT), and the French Center for Agricultural Research for Development (CIRAD) was established in 2018 to develop innovative solutions addressing soil health and sustainability issues, customized to the needs of either smallholder farmers or agricultural companies. The CMPB helps develop solutions addressing efficiency, productivity, and sustainability of agricultural systems beginning with soil and other types of agro-ecological analyses.

Soil functionality depends on soil biodiversity, and regulates decomposition, provides nutrients for plants, regulates water flow and quality, suppresses pathogens, provides pharmaceuticals, and supports above-ground biodiversity.

CMBP defines soil health as the capacity of soil to function as a living, dynamic component of agroecosystems that sustain plants and animals, and ultimately, human livelihoods. Our approach to soil health is essentially a biological one. We study how soil microorganisms interact with each other, with the physical and chemical components of soils, with vegetation, with the cropping system, and how these interactions impact the ecosystem in which they thrive.

We do this by using the following techniques and methodologies:

### Microbiology Techniques

- Isolation, purification, culture and storage of strains
- Characterization of bacterial strains by sequencing
- Production of high-quality inoculants
- Inoculation experiments under laboratory conditions
- Characterization of microbial communities' (bacteria and fungi) genetic and functional diversity
- Assessment of the Arbuscular Mycorrhizal Fungi (AMF) root colonization

### Molecular Biology Techniques

- Extraction of DNA
- DNA amplification by Polymerase Chain Reaction (PCR)
- Characterization of an individual strain
- Characterization of microbial communities by high throughput sequencing

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# Ongoing projects/proposals about Soils and Landscape for sustainability with Chinese partners of CATAS

1. Asian Regional platform on forage legumes launched in December in CATAS. *Research activities are going to be launched in China, Vietnam, Cambodia and Bangladesh. Posting of Dr Zhong (CATAS) at CIAT-Asia in Hanoi for 6 months.*
2. Soil microbial diversity and functions of rubber plantations in Vietnam and China. *Research activities are going to be launched in both countries but ongoing collaboration with the publication of a common scientific paper (Lan et al, 2018 Sciences for the Total Environment, Seasonal changes impact soil bacterial communities in a rubber plantation on Hainan Island, China).*
3. Importance of the mycorrhizae in the farming systems in SEA: example of cassava and legume species such as cowpea widely used in agro ecological systems.
4. H2020 for 2020: Call Europe-China on Soil Health. Chinese consortium requested as to contain 3 different partners.

# Collaboration to build up with CAAS:

# Through the 3 megaprograms

1. MP 1: *S&T Innovation Enables Sufficient Food (STESF)*
    1. **Breeding of new species of legumes with resistant traits:** This can be undertaken in // of the selection of high-effective symbiotic microbial partners such as rhizobia.

2. MP3: *Green Agriculture*
    1. **Ecological function and its restoration of biodiversity on agro-ecosystem:** application of biochar for enhancing soil moisture, soil C content and soil health & Investigations on the importance of roots (and more specially deep roots) to the stabilization of soil organic matter.

# Through CAAS' visiting scientists at CIAT-Hanoi

1. **Regional platform on forage legumes**
2. **CMBP Platform**

International Center for Tropical Agriculture
*Since 1967 Science to cultivate change*

A CGIAR Research Center

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