# From irrigated rice farming to rain-fed rice farming: what solutions exist for sustainable soil fertility management?

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**CARD General Assembly**

# Flooded rice cultivation and rainfed rice cultivation in Madagascar: different soil fertility contexts

| Lowland rice cultivation | Rainfed rice cultivation |
| --- | --- |
| Gleysols (hydromorphic soils)<br>Anoxic conditions: permanently under water<br><br>Slow decomposition of organic matter, methane production<br><br>Fluctuating oxidation-reduction conditions => reduction conditions<br><br>Ferrous toxicity problems: if poorly drained environments and acidic soils (faster solubilisation of Fe)<br><br>Phosphorus availability, but if high Fe concentration => precipitation and possibility of P fixation.<br><br>Highly variable fertility levels | Ferralsols<br><br>Soils with multiple nutrient deficiencies<br><br>Very low fertility<br><br>Very high phosphorus fixation<br><br>Low carbon content<br><br>Very low biological activity<br><br>Very low productivity |

*Common problems: Low soil fertility*

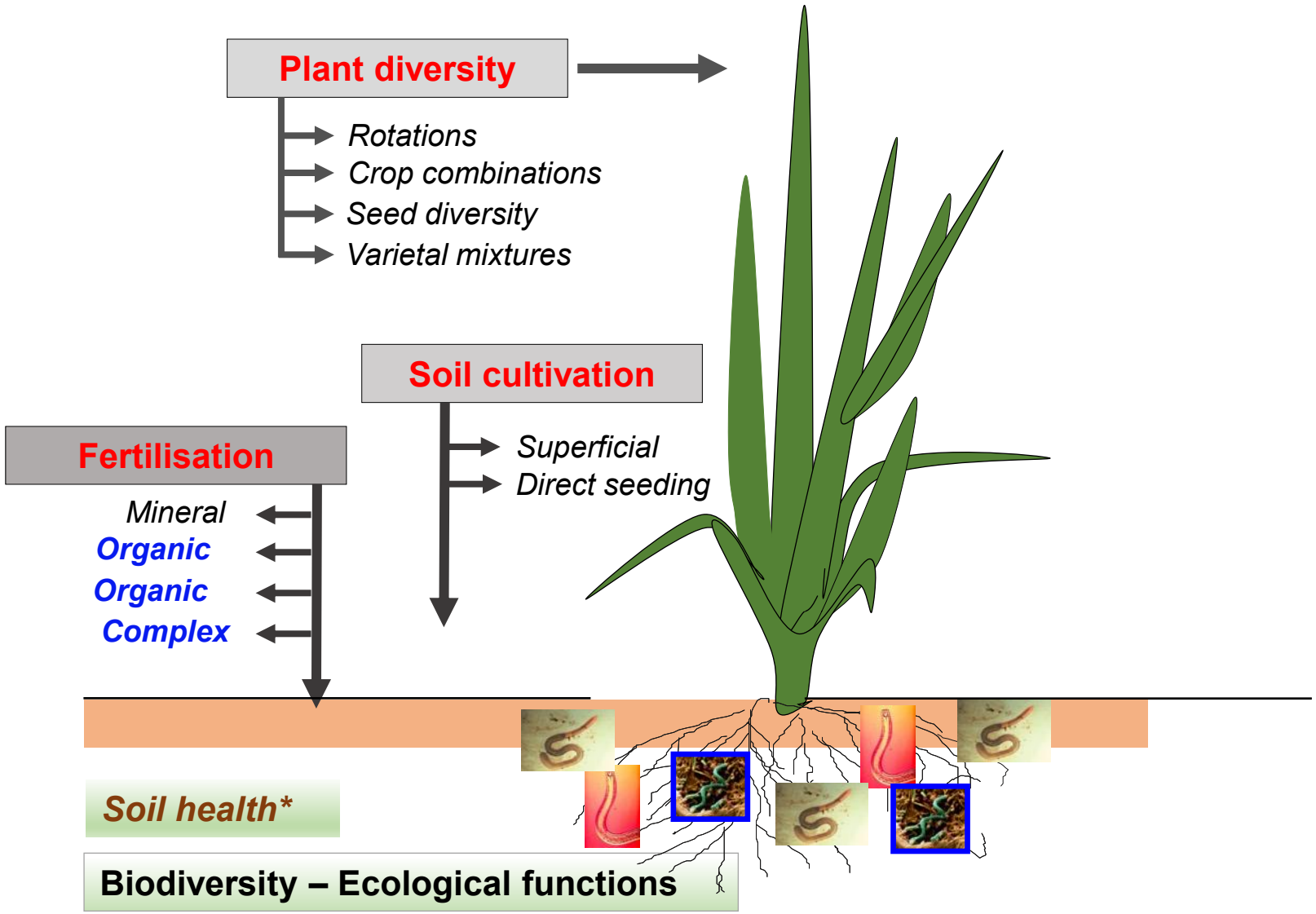
# Sustainable soil fertility management

**Agronomic levers to intensify soil (and plant!) functions in order to manage soil fertility**

# Sustainable soil fertility management

**Agronomic levers to intensify soil (and plant!) functions in order to manage fertility**

- ✓ Manage phosphate input
- ✓ Managing other nutrients
- ✓ Managing organic matter (carbon)
- ✓ Intensify ecological functions



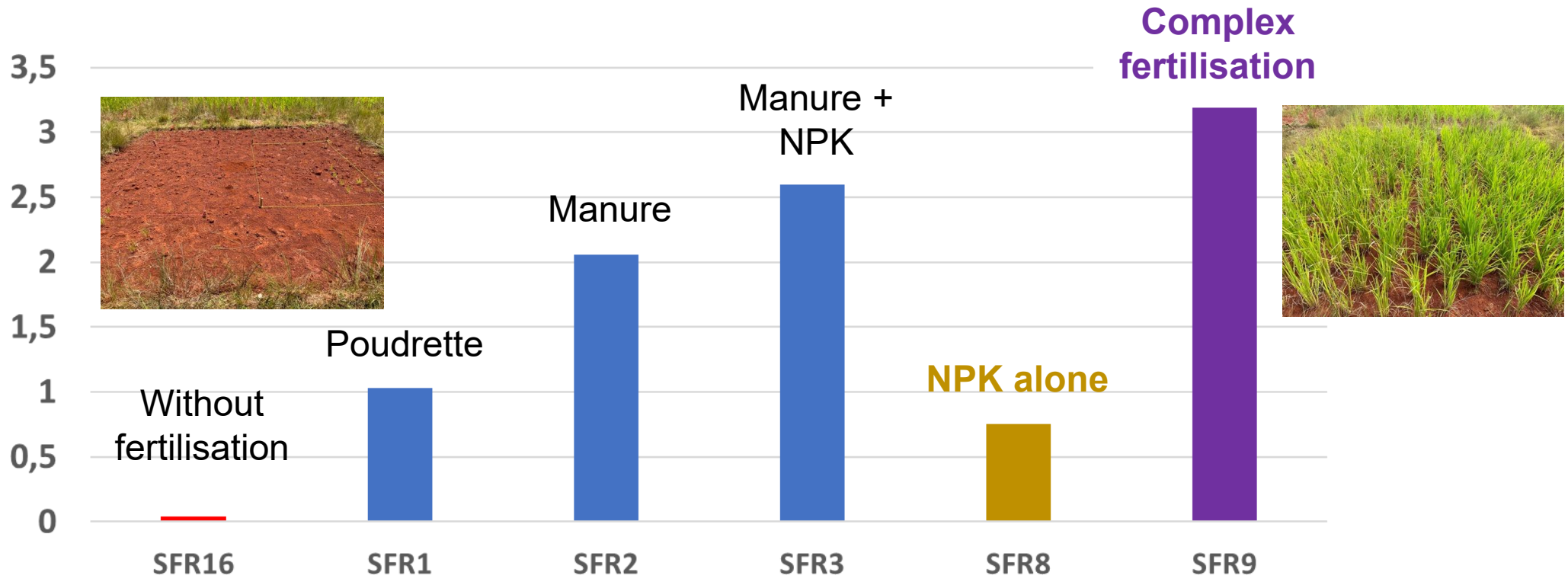

** The ability of soil to provide ecosystem services and maintain the long-term ecological functionality of soils in agrosystems*

# Sustainable soil fertility management

**Optimisation of mineral fertilisation with organic matter**

**Rainfed rice cultivation**

## Rice grain yields (t/ha) – Imerintsiatosika, 2019




SECuRE Project – Imerintsiatosika, 2019

**Mineral fertilisation is not suitable (in particular) for the multiple deficiencies of these soils; it is expensive and unsustainable**

# Sustainable soil fertility management

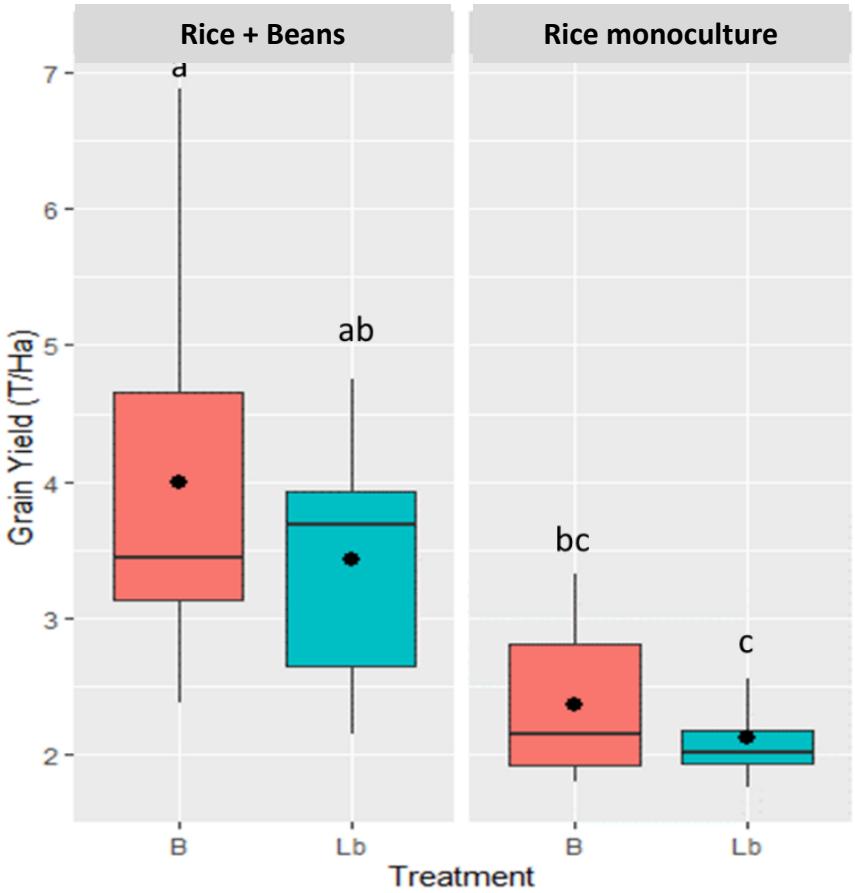
**Investing in the use of available and valuable organic resources**
**+**
**Crop rotation**

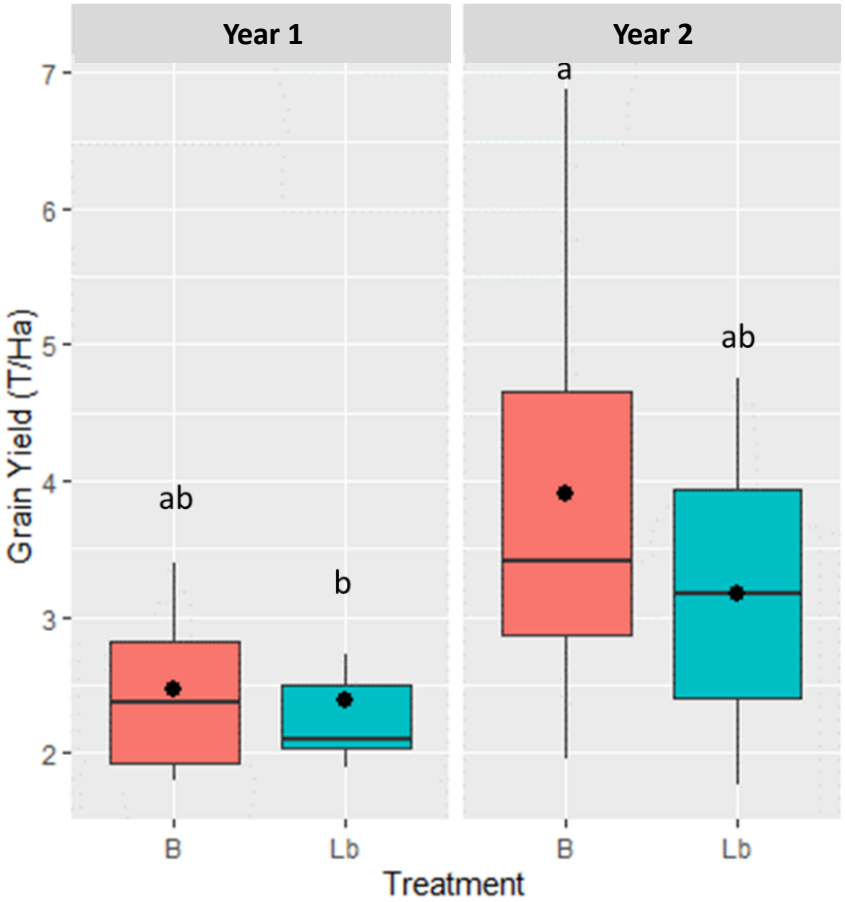

+


**Fertilisers + Legume combination**

**B**: 2.5 T/ha of biochar + 2.5 T/ha of vermicompost)
**Lb**: 5 T/ha of vermicompost

**Rainfed rice cultivation**




Rakotonindrina et al., in prep

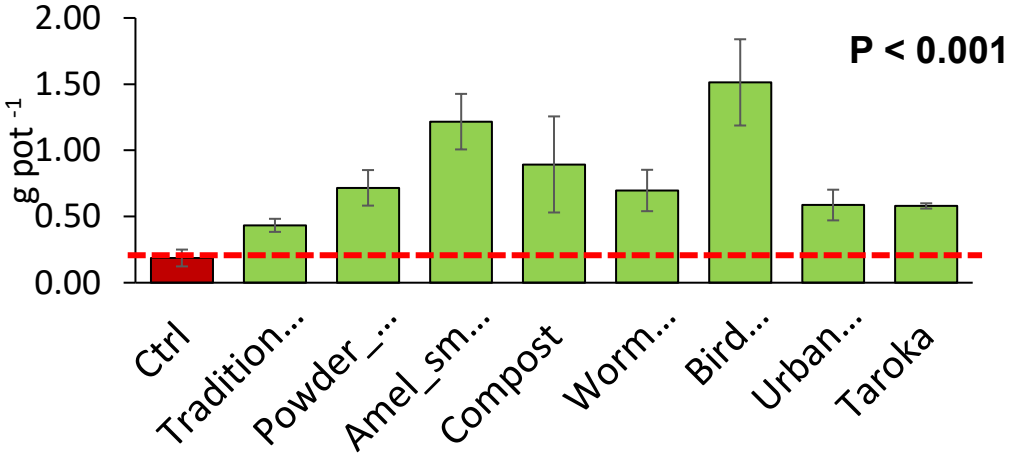
# Sustainable soil fertility management

## Investing in bio-organic fertilisation

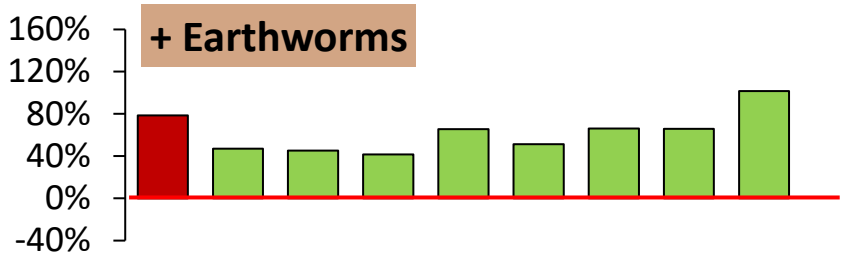
Introduction of organisms into the soil: e.g. earthworms

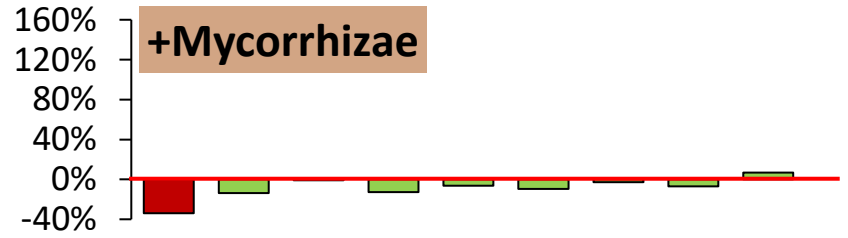
## Assessing the potential and feasibility of **biofertilisation: laboratory studies**

**Without inoculation**




**Rainfed rice cultivation**




Very positive effect of earthworms

Generally neutral or negative effect of mycorrhizae

**Change in the effect of organic amendments on BA following inoculation with soil organisms**

*Herinasandratra V., 2019*

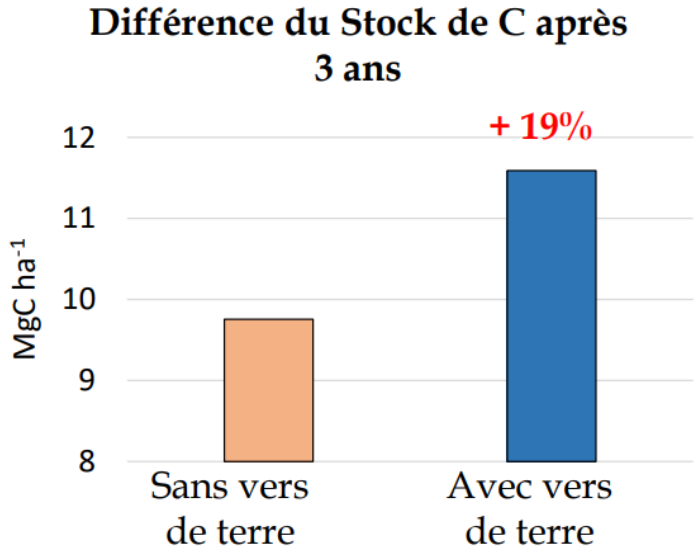
# Sustainable management of soil fertility

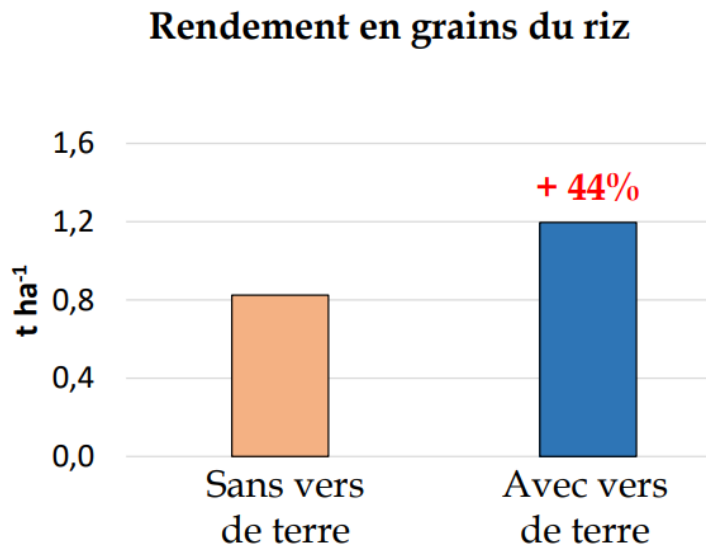
**Invest in bio-organic fertilisation**

## Inoculation of earthworms in the field

**Rainfed rice cultivation**

Lazaina trial (Ratsiatosika, 2018)




Trial monitored from 2013 to 2017 with annual earthworm inoculation at a rate of 75 worms/m$^2$

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Need to add organic matter

**Need to intensify the ecological functions performed by soil organisms**

*Ratsiatosika et al., 2021*

# Sustainable soil fertility management

**Reasoning behind application methods**

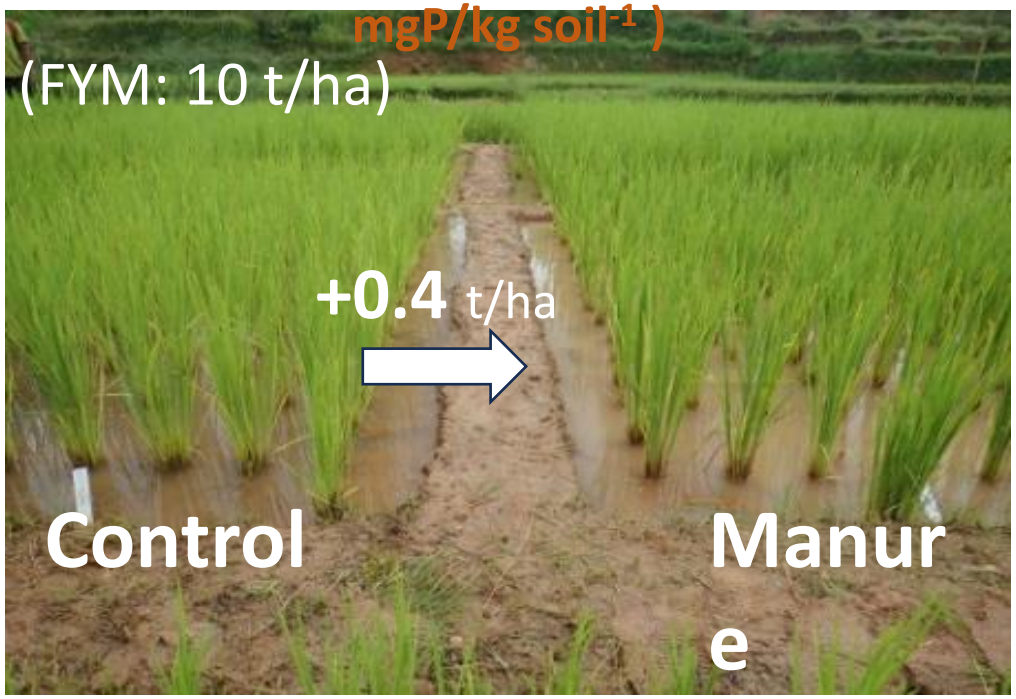
When to apply fertilisers?

**Lowland rice cultivation**

## Effectiveness of manure application

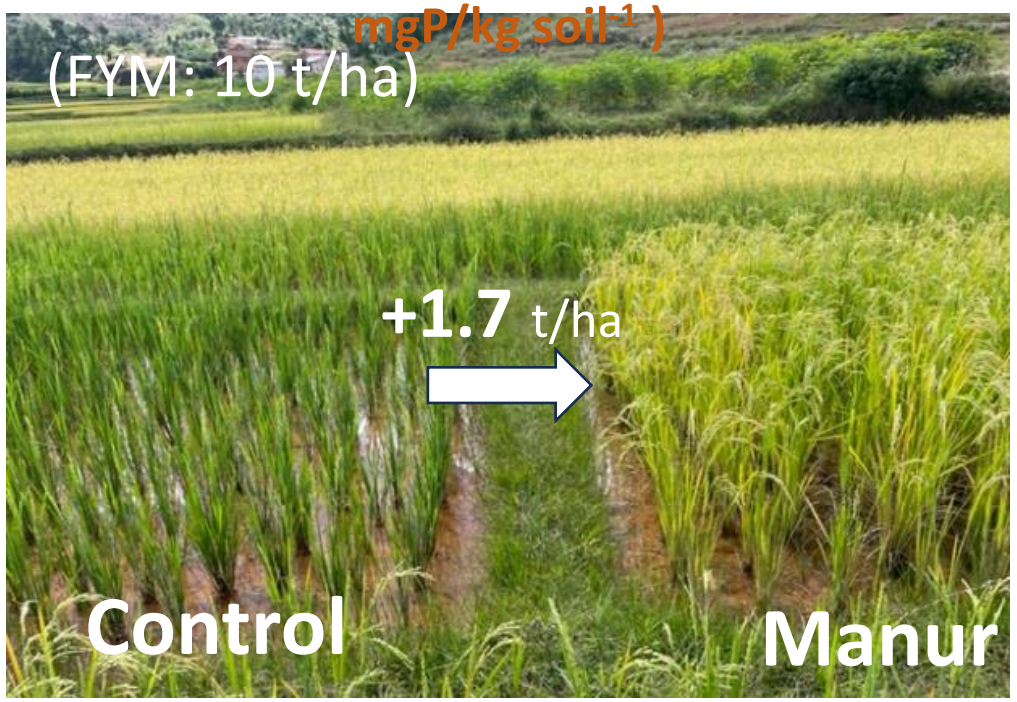
Multi-site trial
2 sites: Antohobe (higher P) and Behenjy (low P)
2 experiments at each site
Same manure dose (10 T/ha), 7-year experiment

**Soil with high phosphorus content (>100 mgP/kg soil$^{-1}$ )**




**Ineffective**

**Soil with low phosphorus content (<100 mgP/kg soil$^{-1}$ )**




**Effective**

Hidetoshi et al., 2025

# Sustainable soil fertility management



When to apply fertilisers?

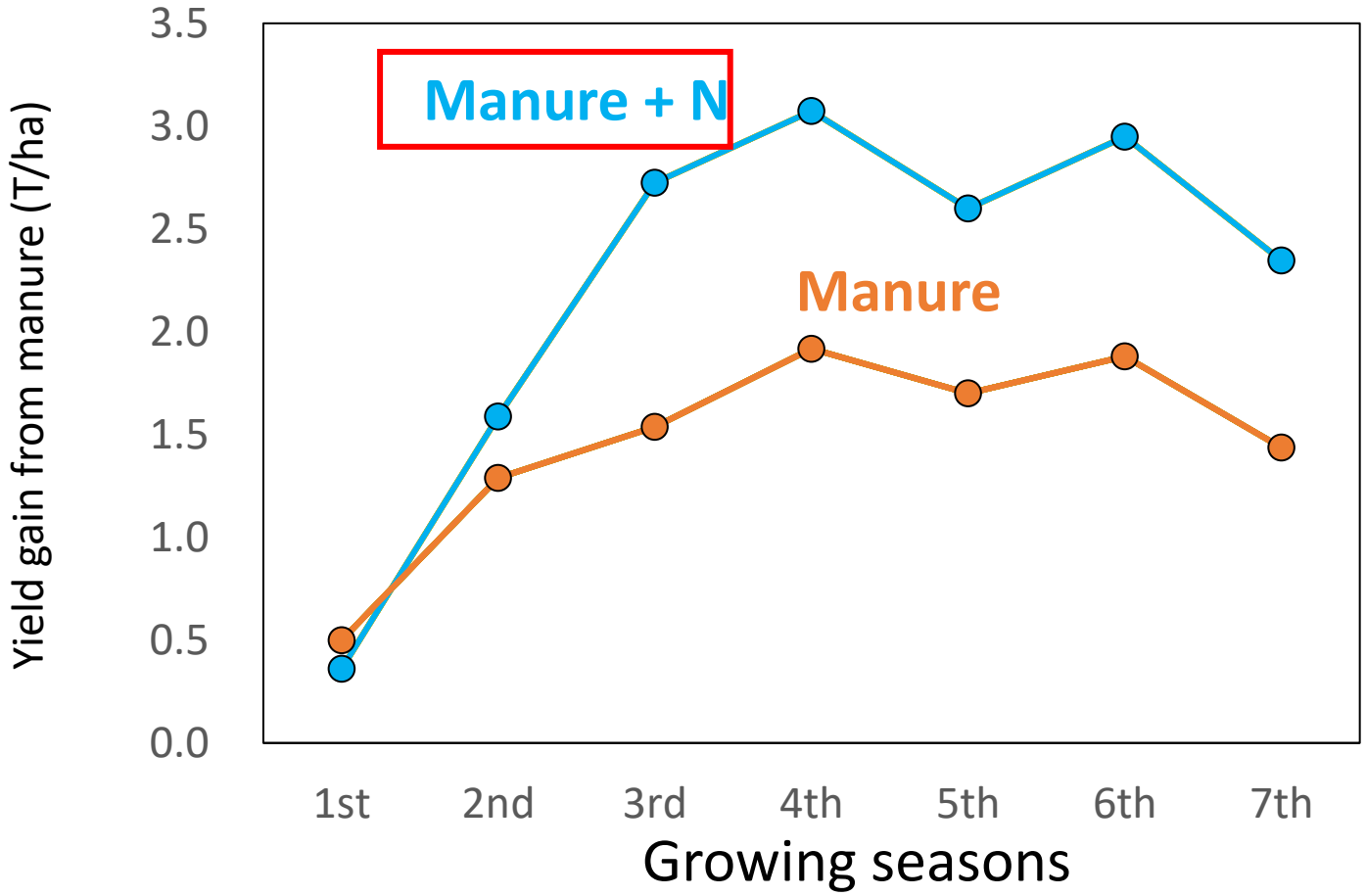
**Lowland rice cultivation**

## Effectiveness of manure application

Multi-site trial
2 sites: Antohobe (higher P) and Behenjy (low P)
2 experiments at each site
Same dose **Manure (10 T/ha)**, **Manure + N** (urea: 80 kg/ha)
7-year experiment

Yield trends over 7 years
Effect over time of manure and manure with mineral fertiliser application

**Low P soil**
(Behenjy)




Hidetoshi et al., 2025

⇒ Continued use of manure is strongly recommended in low P soil.
⇒ After 4 years, the effect is more stable. Reduce the quantities applied.

# Sustainable soil fertility management

## Reasoning behind application methods

When to apply fertilisers?

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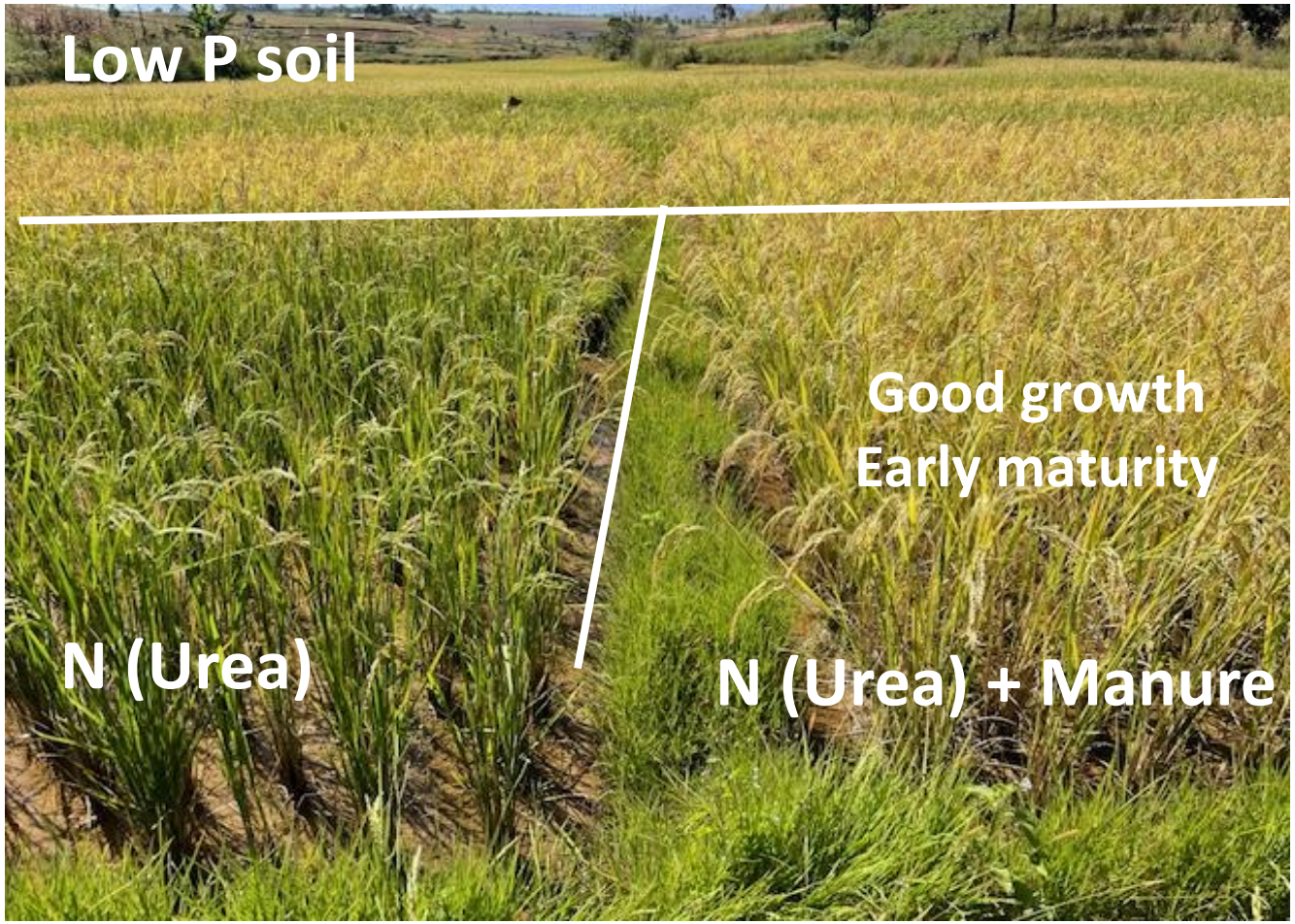



Hidetoshi et al., 2025

⇒ Use a **combination** of manure and mineral fertiliser.

# Sustainable soil fertility management

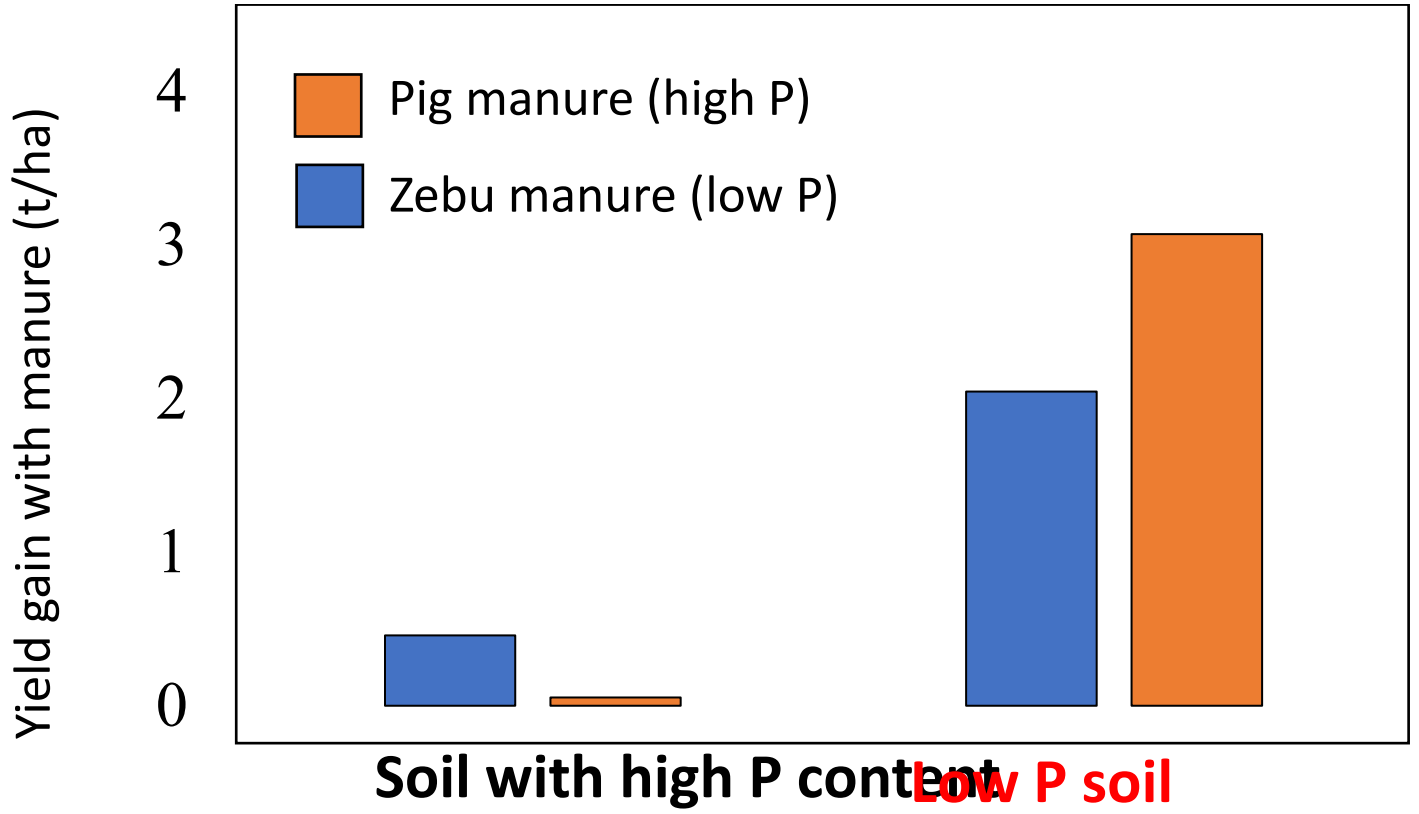
## Reasoning about types of inputs

What types of manure?

**Lowland rice cultivation**

### Comparison of cattle manure and pig manure

Multi-site trial, Antohobe
3 sites: Antohobe (higher P) and Behenjy (low P)
Field trial, 2 years.




Rinasoa et al., 2023

⇒ Both types of manure are effective for low P soils.
⇒ If possible, mix pig manure for manure production.

# Conclusions

- Think carefully about fertility (quality and quantity) and apply it where it is needed
- Manage phosphorus AND carbon effectively!
- Feed the soil AND feed the plant
- Combine materials to address multiple deficiencies
- Check the benefits of certain practices:
  - biochar
  - legumes: nitrogen fixation (P requirement)
  - inoculation of microorganisms
- Climate resilience
- Co-construction with farmers
- Disseminating knowledge
- Need for long-term trials


Thank you for your attention.