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Bounded by Challenge: Navigating Soil Fertility and Toxicity in Guinea-Bissau's Mangrove Rice Ecosystems

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Soil agoecological characterization I

Soil physicochemical characterization and suitability assessment for the coastal mangrove swamp rice production system in Guinea-Bissau – **Catena 2025**

Soil Fertility & Rice Production II

Linking soil fertility and production constraints with local knowledge and practices for two different mangrove swamp rice agroecologies, Guinea-Bissau, West Africa – **Agronomy 2025**

Bridging knowledge and good practices for enhancing soil fertility of mangrove swamp rice upland nurseries in Guinea Bissau through the use of compost. – sub in **Agroecology and Sustainable Food Systems**

Suitable Practices for Soil Ameliorations III

Spontaneous vegatetaion (¨weeds¨) monitoring as key soil bio-indicators in Mangrove rice production agroecologies in Guinea Bissau – **Remote Sensing Applications: Society and Environment**

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To **investigate** and **understand** the *soil fertility and toxicity* constraints that hinder rice productivity, **by co-developing** together with the **local farmers**, **contextually appropriate strategies for restoring soil fertility**.

Characterize the main soil constraints in different mangrove rice agroecologies

Cross-analyze scientific/laboratory results with local farmers' empirical knowledge on soil fertility management & production constraints

Assess the potential effectiveness of low-cost organic fertilization in upland rice nurseries.

Explore the potential of spontaneous weed vegetation as bioindicators of soil health and organic matter dynamics through isotopic methods and remote sensing.

Successive and interactive campaigns between 2021 and 2023 by feedback loop between scientific research & practical local experience

Build a strong bridge between technical knowledge and **local management capacity**

Co-identify, co-design & co-monitor

Principles of "Farmer-back-to-Farmer" where farmer is **active co-researchers**

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Soil agoecological characterization

General agroecological characterization (Initial Topsoil Campagne 2021)

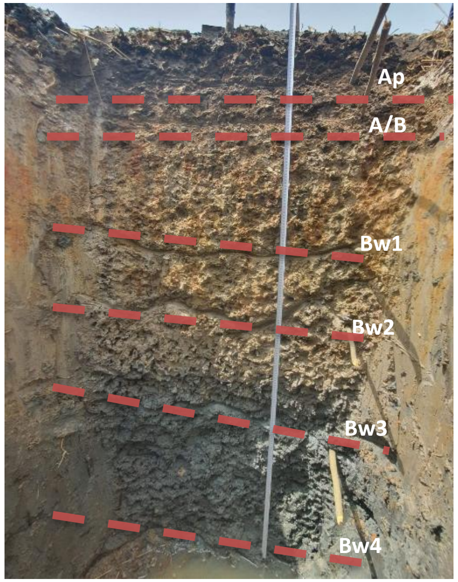
- Tidal Mangroves – TM ➡ **20% of the total area**

Soil salinity and acidity decreased to acceptable levels during rice production

- Associated Mangroves - AM ➡ **70% of the total area**

Less affected by salinity, but shows low levels of nutrients

Comprehensive classification of soil types and sustainability assessment for their limitations (8 soil profiles 2022-2023 and 30 topsoil nursery samples)



Profile	WRB Classification
Cafine TM	Thionic Gleysol (clayic, salic, sodic, vertic)
Cafine AM	Thionic Gleysol (clayic, vertic)
Elalab TM	Eutric Gleysol (arenic, sodic)
Elalab AM	Eutric Gleysol (arenic, sodic)
Malafu TM	Thionic Eutric Gleysol (clayic, salic, sodic)
Malafu AM	Sodic Vertisol (clayic, gleic)
Enchugal TM	Thionic Eutric Gleysol (clayic, salic, sodic)
Enchugal AM	Thionic Eutric Gleysol (clayic, sodic, vertic)

Soil agoecological characterization

Soil Fertility & Toxicity and Constraints in the MSRP System

Northern soils (Elalab area):

- High sodicity
- Degraded structure – sandy soils
- Deficient in essential nutrients

Lowland fields in Central and Southern regions (Oio and Tombali):

- Soil acidification caused by prolonged flooding
- Mineral transformations (e.g., jarosite formation) due to redox processes

Upland nurseries (especially in Oio):

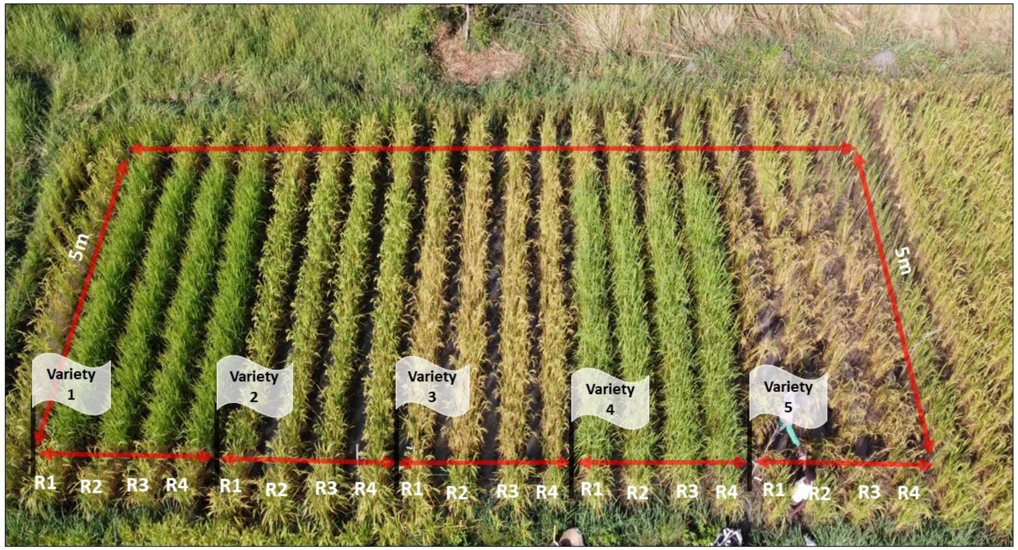
- Highly sandy soils
- Low fertility and poor water retention capacity
- Poor rice seedling development

How do farmers deal with this constraints?

How soil biophysical factors and local practices influence rice productivity?

Soil Fertility & Rice Production

Linking soil fertility and production constraints with local knowledge and practices for two different MSR agroecologies in Guiea-Bissau, West Africa



Field trials in **Oio and Tombali** during **2021–2022**

- 25 varieties tested
- 18 TM and AM (semi-controlled/co-manged by farmers)
- 380 topsoil samples
- Growing parameters at: transplantation, flowering, grain formation & harvesting → Yields (gr/m²)

Productivity outcomes

Oio: 110 g/m² - (saline stress)

Tombali: 250 g/m² - (better water conditions)

Farmers Prefered Varieties ¨***Caublack***¨AM: 170 g/m²

TM :230 g/m²

MRA Statistical Analyses: **81%** for TM

57% for AM

TMs positive drivers: OM, N, K & water availability

AM negative drivers: High sand content, unfavorable pH, low OM, high presence of iron oxides

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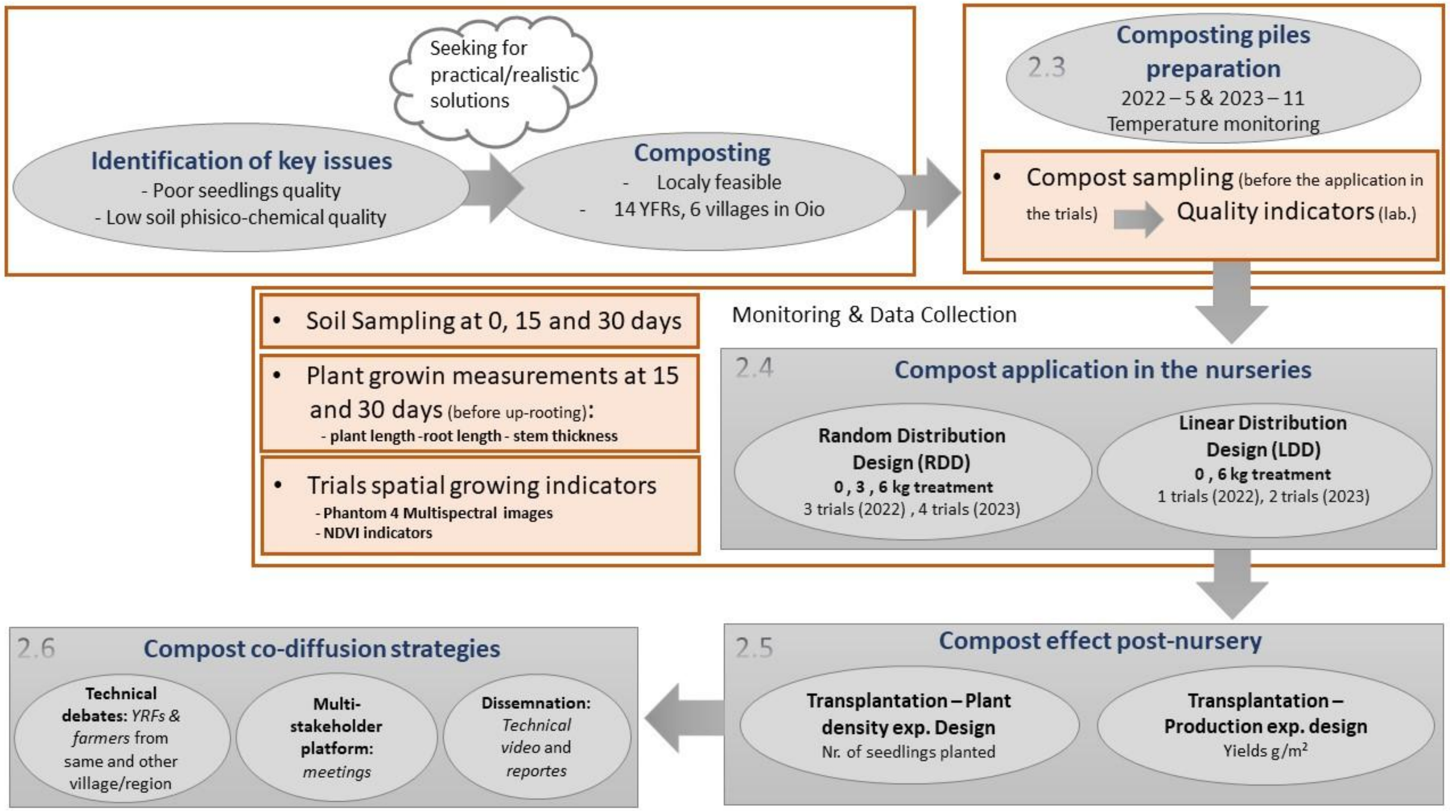
Suitable Practices for Soil Ameliorations

Organic Compost application in **Oio upland nurseries** during **2022–2023**



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Composting piles preparation

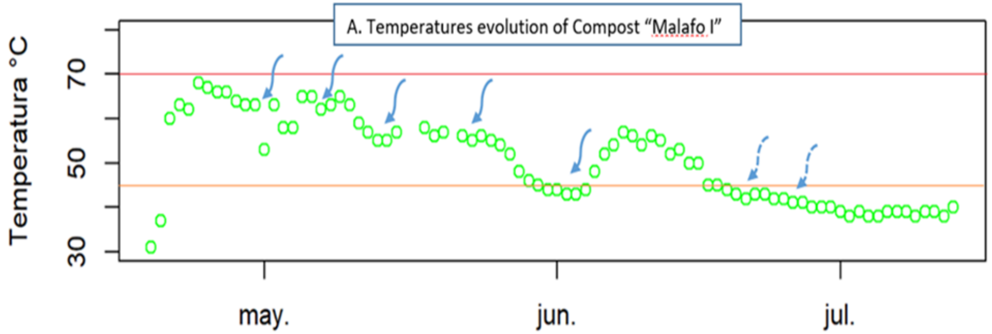
2022 – 5 & 2023 – 11

Preparation: February to June
Temperature monitoring

	Pile 1 – M1	Pile 2 – E1	Pile 16 – E2
Type of materials	(kg)	(kg)	(kg)
Cow manure	202.5	151	198
Green vegetal residues	12 (Azadirachta indica leaves & dry sugar cane)	11 (Azadirachta indica leaves)	17.5 (Azadirachta indica leaves)
Rice straw (dry)	22	38	26
Termite mound	74	123	105
Rice husk	18	20	20
Water	180 L	230 L	300 L
Dry leaves	8 (dry mix leaves)	13 Dry, mango mas vludo (Guettarda pohliana)	12 (dry mix leaves)
Pile dimensiones (H x L x W)/cm	104 x 213 x 170	103 x 200 x 165	105 x 215 x 225
Date of Preparation	19/04/2022	24/04/2022	06/03/2023
Notes			
1. Coverage **2. Location**	1. palm (Eaesis guineensis) branches. 2. in the shade of palm trees.	1. veludo (Guettarda pohliana) branches. 2. in the shade of cashew trees (Anacardium occidentale)	1. mango (Mangifera indica) branches 2. in the shade of cashew trees (Anacardium occidentale)

Baga baga/termiteiro

Neem/acácia (*Azadirachta indica*)



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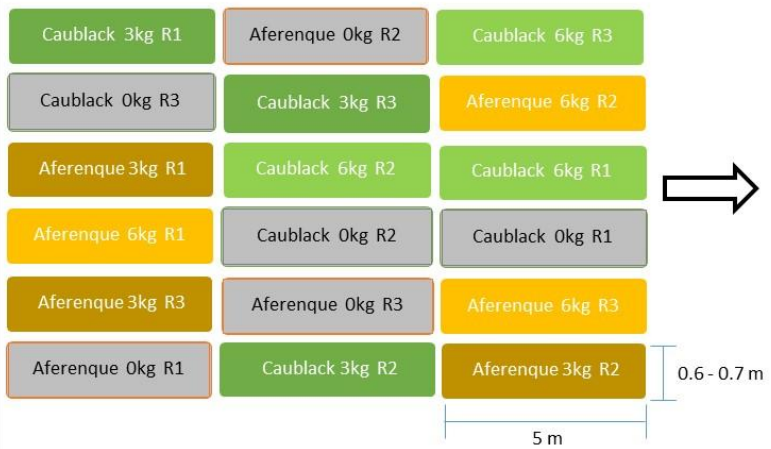
Compost application in the nurseries

Random distributional experimental design - **RDD**

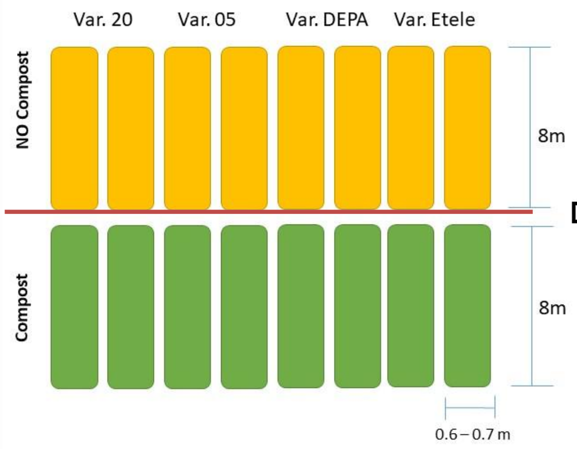
Random ridges assignment x treatment



- 2 varieties
- 3 replicates
- 3 treament
  2 compost doses (3 kg, 6 kg) + Control (0 kg)
- Growing measurements (plant height- stem thickness - root length at 15 days and 30 days after sawing)
- Soil sampling at 15 and 30 days after sawing
- Monitoring the effects post in the mangrove swamp rice fields (post-nurseries)

Linear distributional experimental design- **LDD**

Linear ridges assignment



- 3-5 varieties
- 2 replicates
- 2 treatment
  (1 doses: 1.5 kg/m² ~ 6 kg) + Control (0 kg)
- Growing measurements (plant height- stem thickness - root length at 15 days and 30 days after sawing)
- Soil sampling at 15 and 30 days after sawing
- Monitoring the effects post in the mangrove swamp rice fields (post-nurseries)

Soil Sampling at 0, 15 and 30 days

Plant growin measurements at 15 and 30 days (before up-rooting):
- **plant length -root length - stem thickness**

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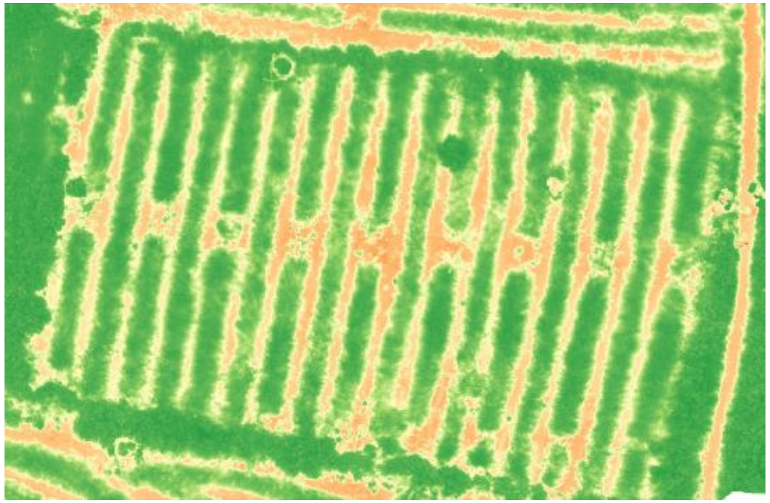
Trials spatial growing indicators

- Phantom 4 Multispectral images
- NDVI indicators

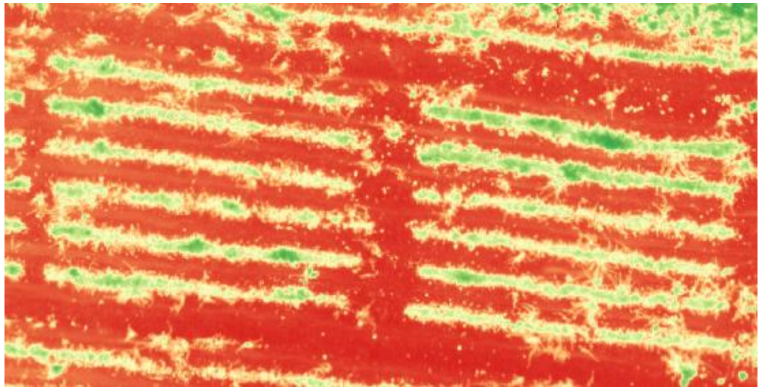
Random distribution experimental design - **RDD**

NDVI



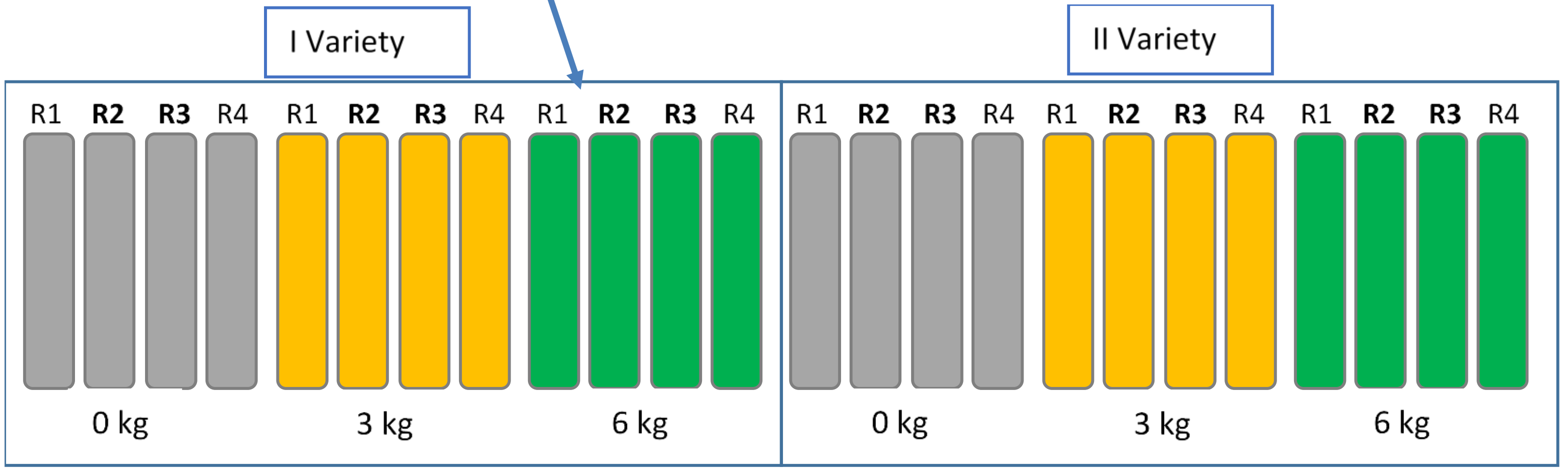
Linear distribution experimental design- **LDD**

NDVI



Transplantation – Plant density exp. Design
Nr. of seedlings planted

Transplantation – Production exp. design
Yields g/m²



- 3 villages
- 17 women
- 3 youngsters

- 4 villages
- 16 field co-monitores trials
- Growth measurements and final production (yield/m²)

Results

Random distribution experimental design - **RDD**

- **Thicker seedlings**
- **Higher leaf N (greenness)**
- **Difficult Visualization for the faremers**

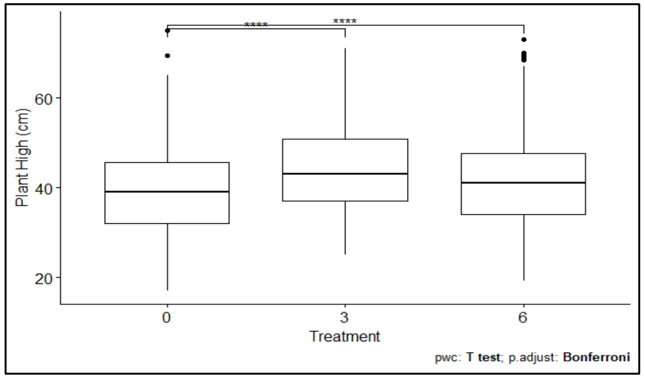
Results

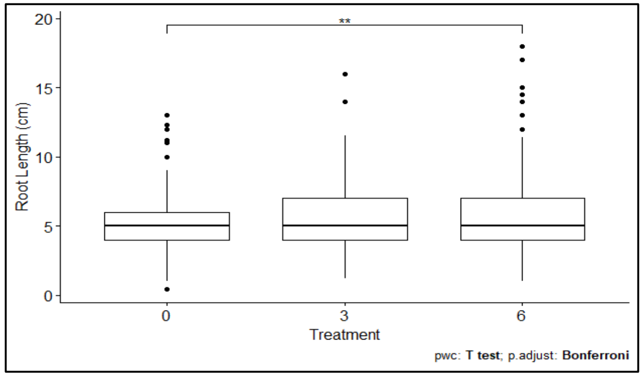
Linear distribution experimental design- **LDD**

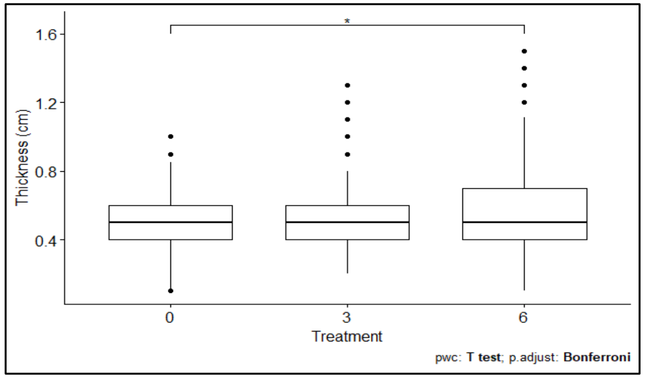
Leaf N (greeness)

Leaf Bronzing

Quick visualization







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Results

- **6 kg** of compost **improved seedling quality**
- **Significant differences** in the vegetation **NDVI index** mainly with **6 kg**
- **Time-saving**: transplanting is possible in just **20 –25 days** - *Climate Change adaptation strategy*
- Helps rice **withstand long dry periods** by **retaining moisture** - *Climate Change adaptation strategy*
- **Pesticide effect** was observed - possibly the ¨**need**¨ in the compost
- Transplantation density **decreases** with **3 & 6 kg compost** nursery seedlings
- Small improvement in production

→In **very poor nurseries** full effects of compost application will become **evident after several years of use**

Enhance soil structure

Enhance seedling radicular system

Enhance uprooting

Results

Lets share good practices!

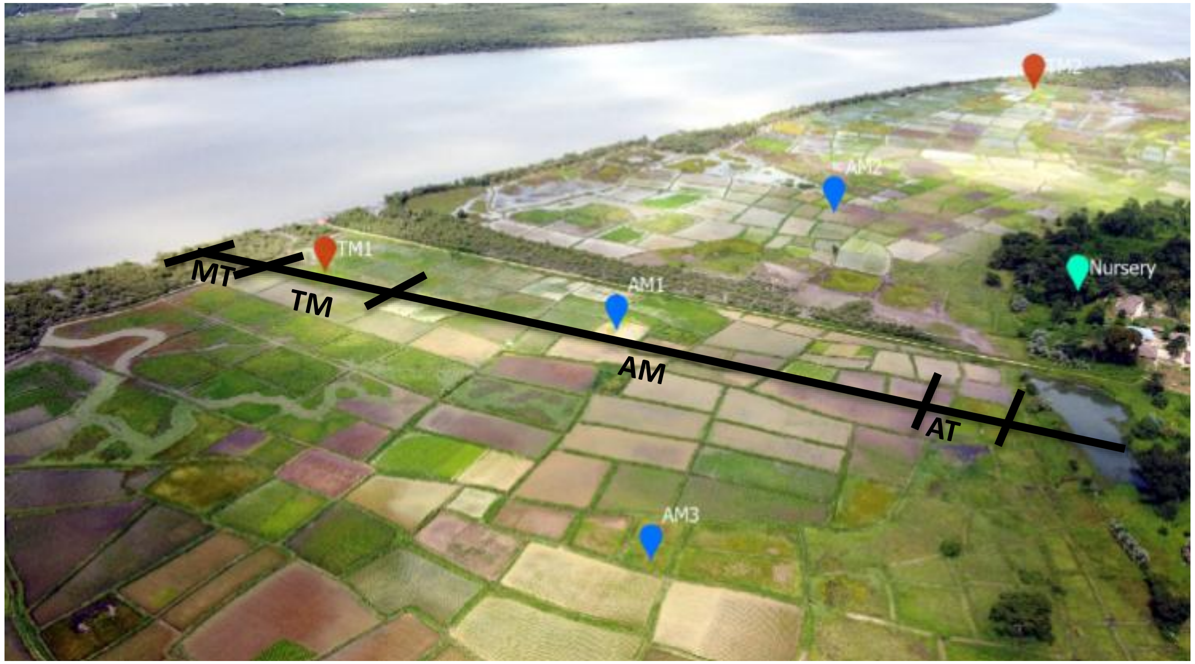
- Participative activities to encouraged technical discussions and evaluation.
- Workshop and roundtables with key national stakeholders.
- Wider dissemination by the farmer-researchers themselves to other areas and villages.
- Farmers significantly **increased compost use** from the **1st** to the **3rd** year
- Divulgation video.

Suitable Practices for Soil Ameliorations

¨Weeds¨ as key soil bio-indicators for sustainable soil fertility practices

- Green biomass (¨weeds¨) is the **main source of organic matter**, especially in the ***AMs*.**

- Mapping the **spatial distribution** of key plant species (weeds) helps understand their bio-ecological roles.
- It is essential to identify the **carbon (C) and nitrogen (N) contributions** of each weed species to assess their impact on soil fertility and rice yield.
- **valuable knowledge** about the different weed species that emerge throughout the rice-growing cycle.



Malugretha – ¨solo i gordo¨ **(A)**
Blutaparon vermiculare
Ncada - ¨i risu¨ - they dont want it in their fields **(B)**
Paspalium Vaginatium

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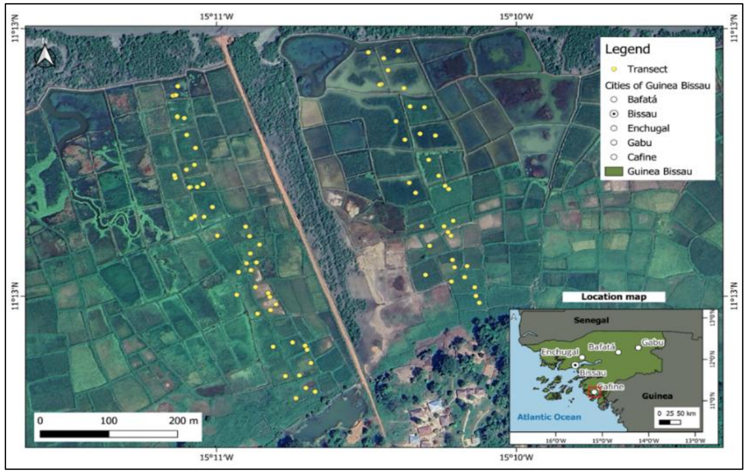
¨**Weeds**¨ as key soil bio-indicators for sustainable soil fertility practices



Drone Transects (*plot by plot*)
Phantom 4 & Mavic Mini 2

Image Classification

Soil, weeds & water samples (*in each plot*)

Trace Isotopic δ^{13}C and δ^{15}N

Echinochloa colona ***(keu)***

Sesuvium portulacastrum

(Malu gretha)

Blutaparon vermiculare

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Results

Image classification accuracy:
88% for TMs
71% for AMs

Echinochloa colona ***(keu)***

Sesuvium portulacastrum ***(Malu gretha)***

Blutaparon vermicular

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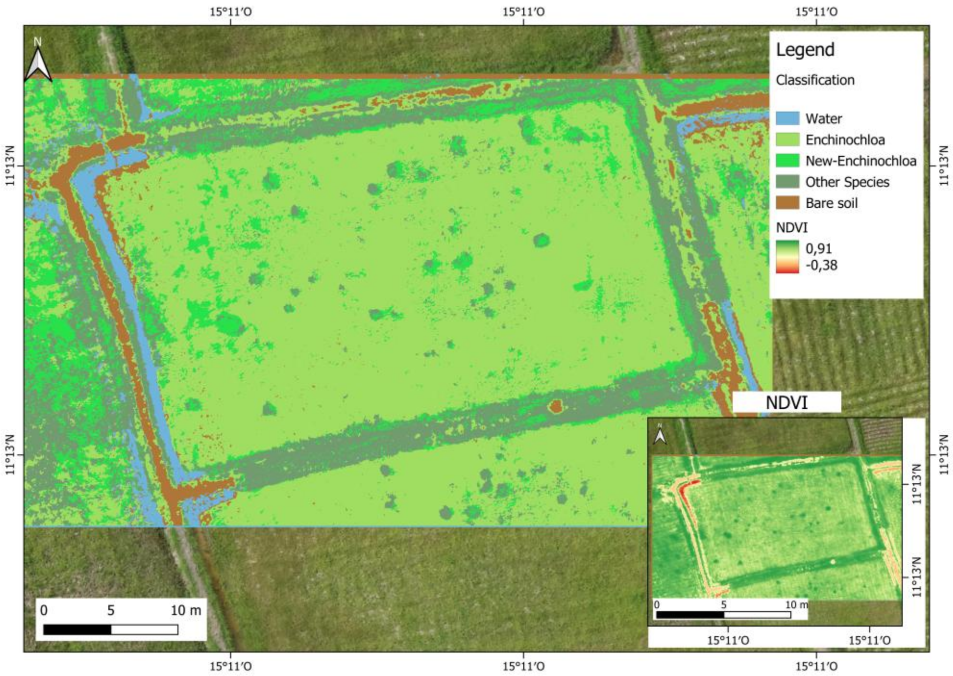
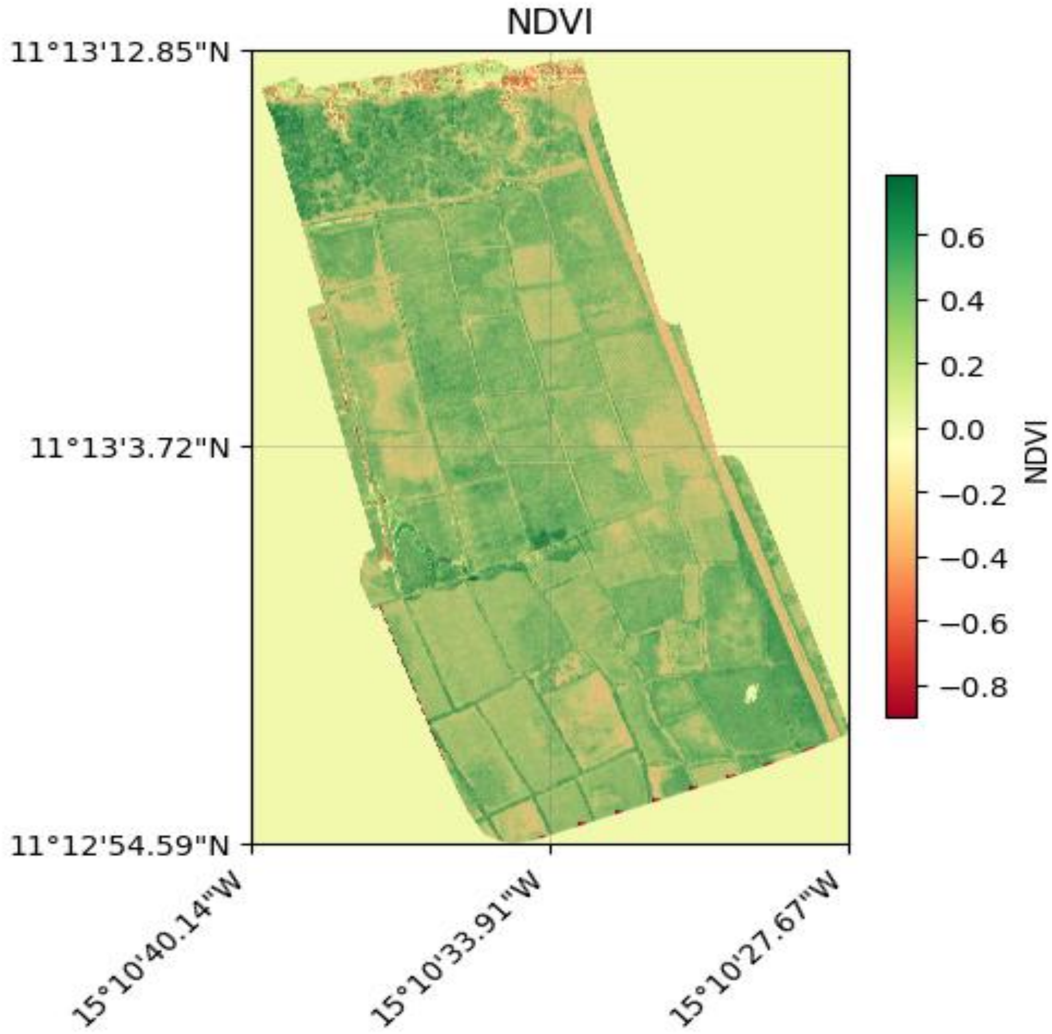
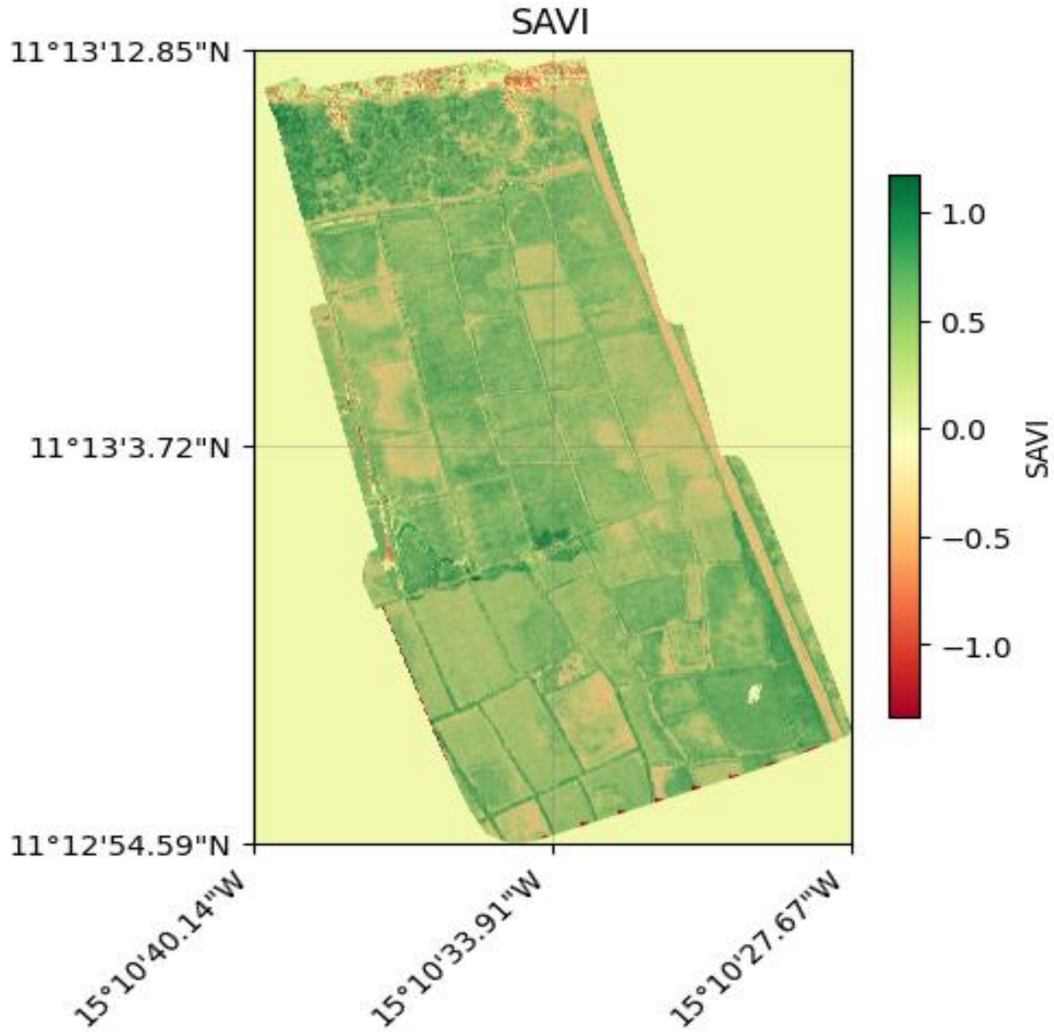
Results



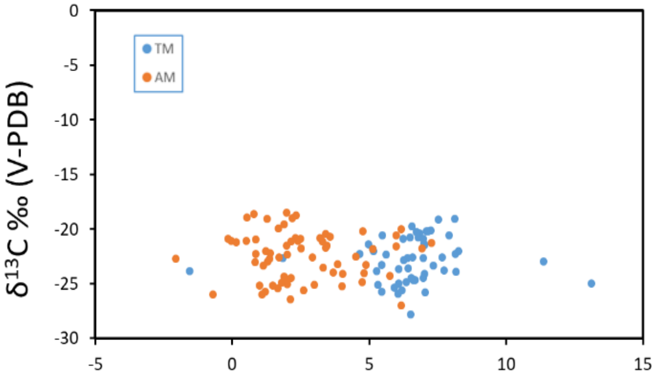
Echinochloa colona
- new shoots ***(keu)***
-Vegetative state

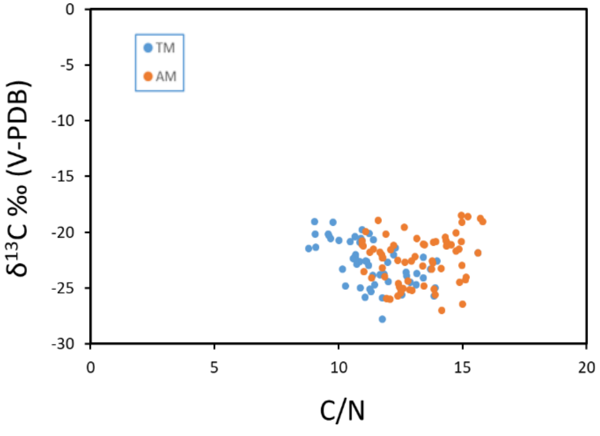
Results


NDVI
11°13'12.85"N
11°13'3.72"N
11°12'54.59"N
15°10'40.14"W
15°10'33.91"W
15°10'27.67"W
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
NDVI


SAVI
11°13'12.85"N
11°13'3.72"N
11°12'54.59"N
15°10'40.14"W
15°10'33.91"W
15°10'27.67"W
1.0
0.5
0.0
−0.5
−1.0
SAVI

Results

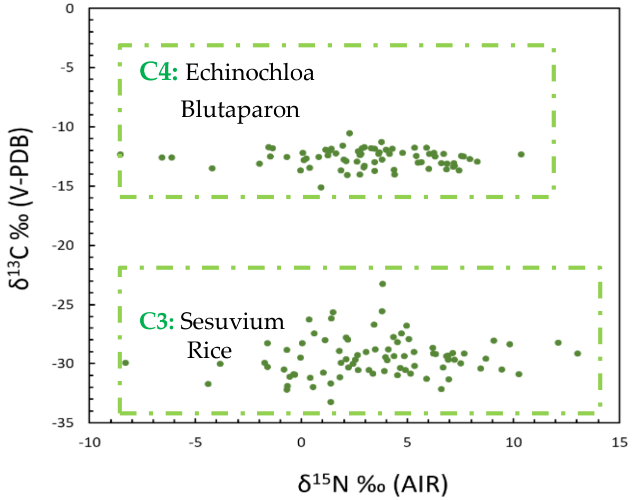


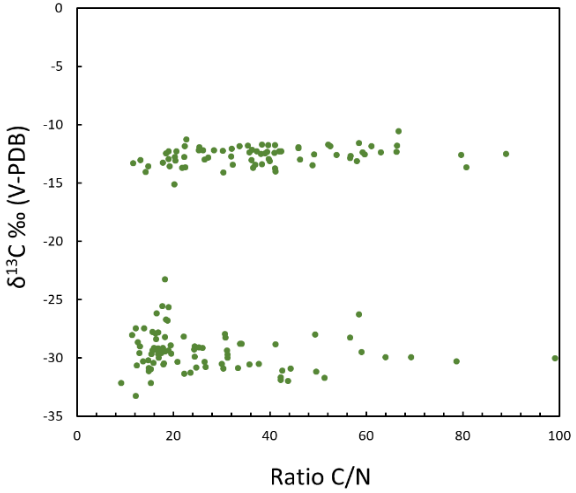


Soils (n=122)

- Robust isotopic distinction between TM and AM soil isotopic signals
- Faster decomposition and potential N mineralization, making soil C and N more available to plants in TMs

Weeds (n=154)





- Clear isotopic distinction between two C3 and C4 species
- % of N is higher in C3 plants

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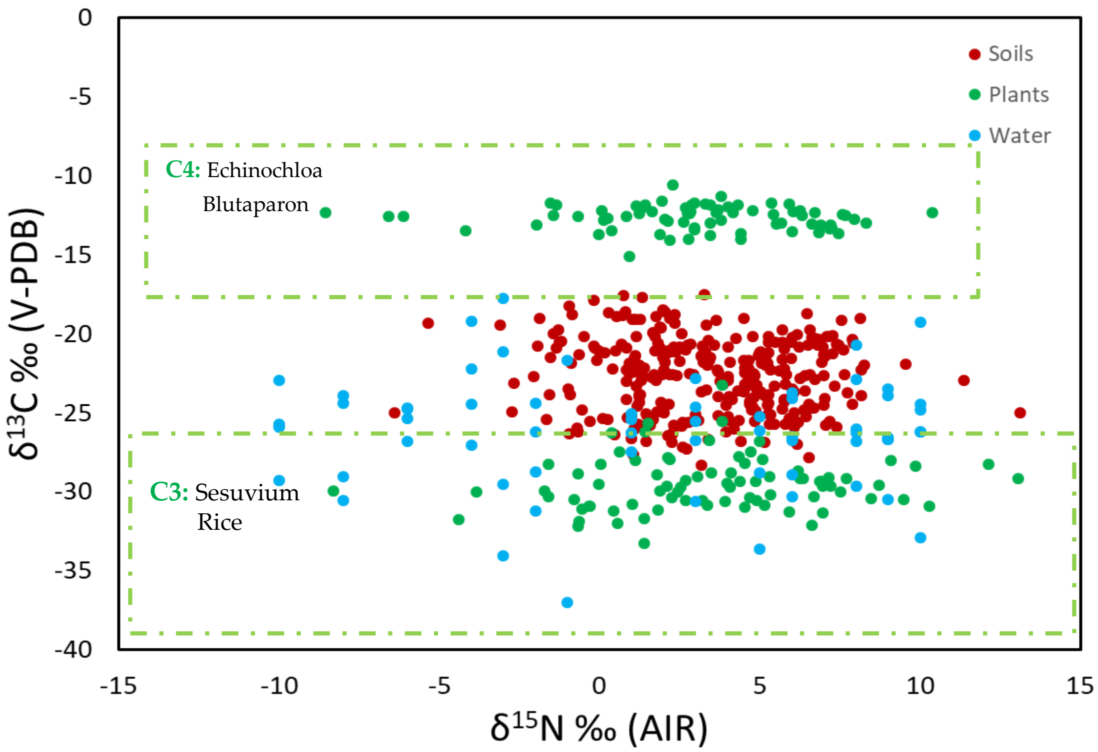
Results



- Stron contribution of C3 *(Sesovium & Rice)* in the soil pools
- C4-derived soil organic carbon (SOC) decomposes more than twice as fast as C3-derived SOC
- Water isotopes display a wide range, indicative of complex hydrological mixing and temporal variability (wet season more negative $\delta^{13}C$)

→Isotopic analyses and RS monitoring together constitute a powerful tool to trace changes
→To prove effective and actionable, they must be further linked and validated locally
→Tools for both beneficial and harmful ¨weeds¨

Muito Obrigado!

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