1st ASEA PhD Days

Virtual meeting

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Impacts of tillage systems on soil organic C dynamics and GHGs emissions under a cassava-based cropping system in Cambodia

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Outline

Context
- Status of Cambodian soil resources
- Agricultural land use
- Characteristic of tillage systems and roles of SOC on soil health
- Research objectives

Materials and Methods
- Location of the research station
- Experimental design and treatment description
- Field operational sequences of Treatments
- Diachronic samplings and study
- Samples preparation and analysis

Study duration and expected outcomes

Activities Plan
Cambodian Soil Resources

- Total land area: **18.1 M ha**
- Soils categorized into **16 groups** (Crocker 1963)
- Land degradation vulnerability
  - Low: **4.6 M ha (26%)**
  - High: **11.8 M ha (67%)**

### Cambodian soil fertility potential (M ha)

- **5.08 (28%)**
- **9.44 (53%)**
- **3.4 (19%)**

Data Sources: The latter from Crocker and Crocker Studies
Legend:
- Rainfall in Millimeter:
  - Less than 750mm
  - 750 to 1100mm
  - 1100 to 1800mm
  - 1800 to 2700mm
  - More than 2700mm
- Soils (Crocker Studies):
  - Acid Lithosols
  - Aluvial Lithosols
  - Alluvial Soils
  - Basic Lithosols
  - Brown Alluvial Soils
  - Brown Lithosols
  - Coastal Complexes
  - Coastal Lithosols
  - Coastal Lithosols
  - Great Lake
  - Grey Lithosols
  - Laterite Alluvial Soils
  - Lateritic soils
  - Pleistocene pedoboles
  - Pleistocene hydrosoils
  - Red-yellow pedoboles
  - Red soils
  - Water Body

General soil map (After Crocker, 1963)
- Total land area: **18.1 M ha**
- Soils categorized into **16 groups** (Crocker 1963)
- Land degradation vulnerability
  - Low: **4.6 M ha (26%)**
  - High: **11.8 M ha (67%)**
The country agricultural crop land use (2018)

- Total agri. land area: **5.56** M ha
- Agri. Land contribution:
  1. Rice: **3.3** M ha
  2. Rubber: **0.43** M ha
  3. Perennials: **1.09** M ha
  4. Annual upland & subsidiary crops: 1 M ha, of which 65% devoted for cassava (ADB, 2021)

Conventional plow and ridge cassava in the Northwest of Cambodia (Trapeang Prasat, Oddar Meanchey)

National average yield in 2020 (fresh tuber) ≈ **18** tons/ha (CDC, 2021)
Status of Cambodian soil and natural resources

Current issues:
- Soil erosion
- Imbalance of soil quality (huge removing > returning)
- Loss of biodiversity and abundances
- Erratic rainfall patterns (climate change)
- Pollution caused by inappropriate uses of agro-chemicals

... maize and cassava production for animal feeds and biofuel ...

Land degradation affects 78,000 km² or 43% of total land area (Bai et al., 2008). Total annual land degradation costed 677 M US$ equivalent to 8% of GDP based in year 2007 (UNCCD 2018)

Soils need to be recognized and valued for their productive capacities as well as their contribution to food security and the maintenance of key ecosystem services
Impacts of conventional tillage on fertility

Soil erosion assessment of ridge-based cassava, Northwest of Cambodia in 262 days (Feb 2015 – Jan 2016)

- **Eroded soil (T/ha)**
  - 0
  - 20
  - 40
  - 60
  - 80
  - 100
  - 120

- **Thickness (mm)**
  - 6.8
  - 4.0

- **Eroded QTY**
  - 8
  - 6
  - 4

Thickness: 8 mm, 6 mm, 4 mm
Eroded QTY: 119 T/ha, 80 T/ha, 60 T/ha

CARDI, 2017 (IDM project)
Global Carbon stock:
1. Living organisms: 560 GT (Gigaton)
2. Atmosphere: 800 GT
3. Soils: 1,500 GT

Soils like a 2-side-blade sword!
It can be a sink or sources of GHGs
(Oelkers & Cole 2008)

* 1 GT = 1,000,000,000 tons

Adapted from UPSC: https://targetupsc.in/post3/what-is-soil-organic-carbon
Conservation Agriculture (3 pillars, Impacts and Co-benefits)

**Impacts:**

- Climate Change mitigation
- Soil improvement (reduce erosion, increase fertility and water retention)
- Yield improvement and resilience (Food security and increase livelihood)
- Biodiversity and environment conservation

**1. Carbon emissions reduction**
- Minimum or no soil tillage

**2. Carbon sequestration**
- Permanent soil cover

**3. Enhance biodiversity**
- Species diversity and spatial arrangement

**CO2**

- Enhance biodiversity
- Carbon sequestration

**Impacts:**

- Climate Change mitigation
- Soil improvement (reduce erosion, increase fertility and water retention)
- Yield improvement and resilience (Food security and increase livelihood)
- Biodiversity and environment conservation

**CO2**
The study is complementary of the study on the impacts of land use and land cover changes that is also funded by ASSET.

The **overall goal** of the study, at field scale, aims to quantify the changes in SOC fractions and GHG emissions from a *medium-term experiment (13 years)* under different tillage systems.

The **specific objectives** are to assess the changes in:

1. **Diachronic measurement of SOC and N stocks** under conventional tillage and different CA-based cropping systems;

2. **SOC fractions** (amount and characteristics of the C associated to soil particle size fractions); and

3. **Greenhouse gas emissions (GHGs)** under conventional tillage and CA-based cropping systems during **two consecutive** cropping seasons.
Geography

- **Location**: Chamkar Leu, Kampong Cham
- **Coordinate**: 12°12'31.7"N 105°19'08.6"E
- **Altitude**: 101-500 m above sea level
- **Soil type**: Red Oxisol
- **Parent matl.**: Basalt (volcanic rock)
- **Station area**: 14.5 ha
- **Begin of CA**: established in 2004
The experiment (selected for the study) comprising of four tillage cropping systems, implemented on 8m × 37.5m plots, laid out in a Randomized Complete Block Design (RCBD), with 3 replicates, covered a total area of 3,600m².

Fertilization

a. Basal: (0-35-0) in mid Apr.
   Thermphosphate 200 kg/ha

b. Top dressing
   • Biopump: (0-0-30)
     KCl 50 kg/ha 30 DAS
   • Maize: (70-30-0)
     16.20.0 150 kg/ha 0 DAS
     Urea 50 kg/ha 25 DAS
   • Cassava: (46-0-60)
     KCl 50 kg/ha 30 DAP
     Urea 50 kg/ha 30 DAP
     KCl 50 kg/ha 90 DAP
     Urea 50 kg/ha 90 DAP
Experimental Design and Treatment Description

The experiment (selected for the study) comprising of four tillage cropping systems, implemented on 8m × 37.5m plots, laid out in a Randomized Complete Block Design (RCBD), with 3 replicates, covered a total area of 3,600m².

**Treatment Description:**

T1 – CT: Monocropping of cassava under Conventional tillage with disc plowing to a 15-20 cm depth represents farmers’ practices

T2 – CA1: Monocropping of cassava under no tillage system with previous crop’s biomass returned to the soil

T3 – CA2 and T4 – CA3: Bi-annual rotation under no tillage system in which the main crop (i.e., cassava), was grown in bi-annual rotation with maize.

**Notice:**
In CA1, CA2, and CA3, legume cover crop (*Stylosanthes quianensis*) was grown in association in the middle of inter-row with the main crops.

If the development and/or density of the cover crops sown previous year considered as insufficient, fast-growing shorth cycle species (mix of millet + sunnhemp + cowpea) were sown as cover crops at the beginning of rainy season prior maize cultivation.

**Fertilization:**

a. **Basal:** (0-35-0) in mid Apr.
   Thermphosphate 200 kg/ha

b. **Top dressing**
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     KCl 50 kg/ha 30 DAS
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     KCl 50 kg/ha 90 DAP
     Urea 50 kg/ha 90 DAP
Field Operational Sequences of the Treatments (2021)

**T1 – CT**: Monocropping cassava

- Basal fert.
- 1st plow

- Planting (NTP)
- Spray herb.

- 1st weeding 1st fert.
- 2nd weeding

- 3rd weeding 2nd fert.

- Harvest Biomass & tubers

**T2 – CA1**: Monocropping cassava

- Basal fert.

- 1st plow

- Planting (NTP)
- Spray herb.

- 1st weeding 1st fert.

- 2nd weeding

- 3rd weeding 2nd fert.

- Harvest Biomass & tubers

**T3 – CA2**: Bi-annual rotation maize/cassava

- Basal fert.

- 1st fert.

- Planting (NTP)
- Biopump (NTP)

- Post herb.

- Harvest Biomass & grain

**T4 – CA3**: Bi-annual rotation maize/cassava

- Basal fert.

- 1st fert.

- Maize (NTP)

- Harvest Biomass & grain
Timeline: Experiment & Diachronic Samplings

Expr. establishment
• Pre expr. sampling


2nd sampling of Dr. Lyda’s PhD
• Samples for analysis
• Auger: 7 soil layers

1st sampling of Dr. Lyda’s PhD
• Samples for analysis
• Bulk density
• Aggregate samples
• Open soil pits: 7 soil layers

3rd sampling of Vira’s PhD
• Samples for analysis (SOC & and Fractionation, Rock-Eval)
• 1 pit + 4 points by automated auger
• Soil depths: 7 soil layers

GHGs sampling of Vira’s PhD
• 2 years: April, 2022 - Feb, 2024
• Closed chamber

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Methodology

- Open 1 pit (1m x 1m x 1m) at the center of the elementary plot. Sampling on 3 sides of the pit, keep individual sample then make composite after processing (air-drying, sieving, homogenizing, and archiving) for Lab analysis.
- Additional 4 sampling points to be obtained by an automated auger. Keep individual sample from each sampling point for further processing (air-drying, sieving, homogenizing, and archiving).

Samples collected

- Disturbed samples: 4 T x 3 RPLs x 7 individual samples/RPL x 7 depths = 588 individual samples
- Bulk density samples: 4 treatments x 3 replicates x 3 samples/replicate x 7 depths = 252 β samples
Distributed samples (SOC & N and Fractionation)

- Individual sample obtained from the field will be air-dried at room-temperature, sieved (2mm-mesh), and homogenized, and finally composited to make 1 sample/elementary plot.
- Assessment of moisture content (10g each) at 105°C for 48 hours at Bos Khnor station
- Samples for Total SOC & N analysis by dry combustion (1 composite x 4 treatments x 3 replicates x 7 layers = 84): to be ground & packed (with clear label ≈ 10g each) for shipping to France in early 2022
- Samples for fractionation (1 composite x 4 treatments x 3 replicates x 7 layers = 84 samples): 200g each (lab’s analysis + reserve) to be fractionated at RUA’s soil lab
- After separation, each size fraction (> 53 µm and < 53 µm) ground, and 10g each (POC & MAOC) shipped to France in early 2022. The remaining QTY of each fraction will be archived.

Bulk density

- Fresh weight (for cross-checking with dried mass just in case human error occurs)
- Oven dried at 105°C for 48 hours at Bos Khnor station
- Dried weight
- Calculation: mass/ha/layer
Associations between soil particles and their special arrangement are important for SOC dynamics.

- **Particle size fractionation**: to measure the turnovers of the amount of SOC pools, i.e., particulate organic C (POC) as an indicator of overall enhancements of soil health, i.e., aggregate stability, aeration, infiltration, nutrient cycling, ... and mineral associated organic C (MAOC) at 53-µm particle size class.
- The fractionation procedure involves a combination of two methods:
  1. **Chemical dispersion** using Sodium Hexametaphosphate (Na-HMP) as the separation agent; and
  2. **Physical dispersion** sieved through 53-µm mesh sieve

- **Nature of SOC Stability** (Rock Eval Pyrolysis): to identify the characteristics (type and maturity) of SOC
- After fractionation, 3 depths (upper, medium, and bottom) per elementary plot of each fraction will be selected for the analysis using Rock-Eval Pyrolysis analyzer using approx. 100 mg sample heated from 300°C to 550°C (at 25°C/min) in an inert atmosphere (helium) to quantitatively and selectively determine (1) the free hydrocarbons contained in the sample and (2) the hydrocarbon- and oxygen-containing compounds (CO2) that are volatilized during the cracking of the unextractable organic matter in the sample (kerogen).
Particle size fractionation scheme adapted from Hok et al. (2015) for separating POC and MAOC using combination of physical and chemical SOC pool extraction methods.

- **40 g soil sample**
- **Dispersion**
  - 1.25 g Na-HMP + 100 mL deionized H₂O
- **Store suspension 16 h at 10°C**
- **Add Ø10-mm agate balls (3) + shake 100 rpm 8 h**
- **Wet sieving (53 µm mesh)**
  - **Soil fraction > 53 µm (POC)**
    - Siphoned, oven-dried at 40°C, and dry mass
    - Grinding
    - Total C analysis
  - **Soil fraction < 53 µm (MAOC)**
    - Siphoned, oven-dried at 40°C, and dry mass
    - Grinding
    - Total C analysis
- **Flocculation**
  - 2 g CaCl₂
Green House Gases (GHGs) Sampling

- The GHGs will be measured in 2-continuum years at 10 month each (April 2022 – Feb 2023 and Apr 2023 – Feb 2024)

- 6 closed-static chambers will be deployed per elementary plot to collect the GHGs (CO₂, CH₄, and N₂O) samples

- Gas samples will be collected through a septum using a polypropylene syringe and stored in evacuated vials at every 2-week interval. In addition, the samples will also be collected right after the implementation of main field operations (land preparation, planting, weeding, fertilization, harvest, ...) and climatic events (rainfall, ...)

- The samples will be shipped to New Zealand for the GHGs content analysis once every 2 months

- In the analysis, the GHG concentration of the samples will be measured by Gas chromatography–mass spectrometry (GC-MS)
Study Duration and Expected Outcomes

**Duration**
- Three (3) years period from October 2021 to September 2024

**Expected outcomes**
- To draw an assessment of mitigation potential (SOC/N, GHGs) of conventional plough-based tillage (CT) and conservation agriculture cropping systems (CA) for the Red Oxisol in Cambodia.
- Three (3) articles are targeted to be published in high-impacted peer-reviewed journals:
  1. Medium-term Soil organic C and N stocks
  2. Amount and characteristics of the C associated to soil particle size fractions; and
  3. Greenhouse gas emissions (GHGs) under conventional tillage and CA-based cropping systems
Activities Plan

**2021**
- REG at GAIA
- Literature review
- Full proposal DEVT.
- Signing the AGMT

**2022**
- Soil sampling and processing
- Lab analysis (SOC & N, Frac)
- Implement field operations of cropping season 2022
- GHG sampling 1st yr (10 months)
- Harvest cassava
- GHGs analysis every 2 months (NZ)
- Computing & interpreting data (SOC & N, Frac)
- GHGs analysis every 2 months (NZ)
- 1st ASENA PhD Day

**2023**
- Implement field operations of cropping season 2023
- GHG sampling 2nd yr (10 months)
- Harvest cassava
- Articles submission
- Writing 1st & 2nd chapter (SOC & N, Frac)
- GHGs analysis every 2 months (NZ)
- Presentation Findings in international conference

**2024**
- Writing 3rd chapter (GHGs)
- GHGs article submission
- Project wrap-up
- Thesis defense
- Graduation

**Articles Submission**

**Presentations**