ASEA

Agroecology in SouthEast Asia

1st ASEA PhD Days

Virtual meeting

1st - 2nd December, 2021 | 14:00-17:00 GMT+7

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

Vira LENG[a,b], Laurent THURIES[c], Remi CARDINAEL[c], Vang SENG[a], Florent TIVET[c,d], Pascal LIENHARD[c,d], Stephane BOULAKIA[c], Lyda HOK[e] and Clever BRIEDIS[f]

a: Department of Agricultural Land Resources Management, General Directorate of Agriculture, Ministry of Agriculture, Forestry, and Fisheries, Phnom Penh, Cambodia
b: Doctoral School GAIA, SupAgro Montpellier, University of Montpellier, Montpellier, France
c: CIRAD, UR AIDA, Avenue Agropolis, 34398, Montpellier, France
d: Agroecology and Safe Food System Transitions in Southeast Asia Project (ASSET)
e: Department of Soil Science, Faculty of Agronomy, Royal University of Agriculture, P.O. Box 2696, Phnom Penh, Cambodia
f: State University of Ponta Grossa, Av. Carlos Cavalcanti 4748, Campus de Uvaranas, 84030-900, Ponta Grossa, Brazil

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Funded by:

Outline

Context

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

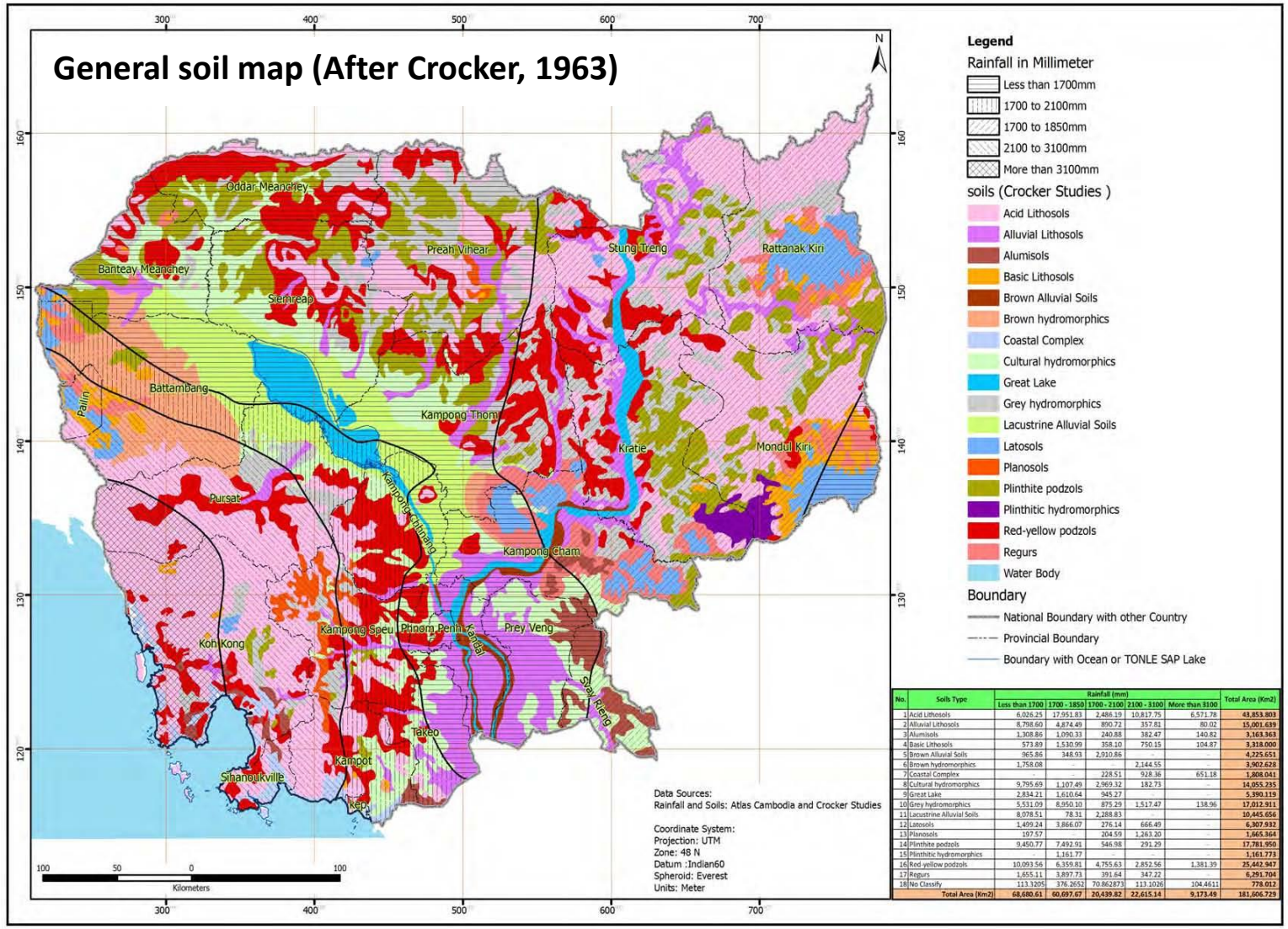
Materials and Methods

- 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

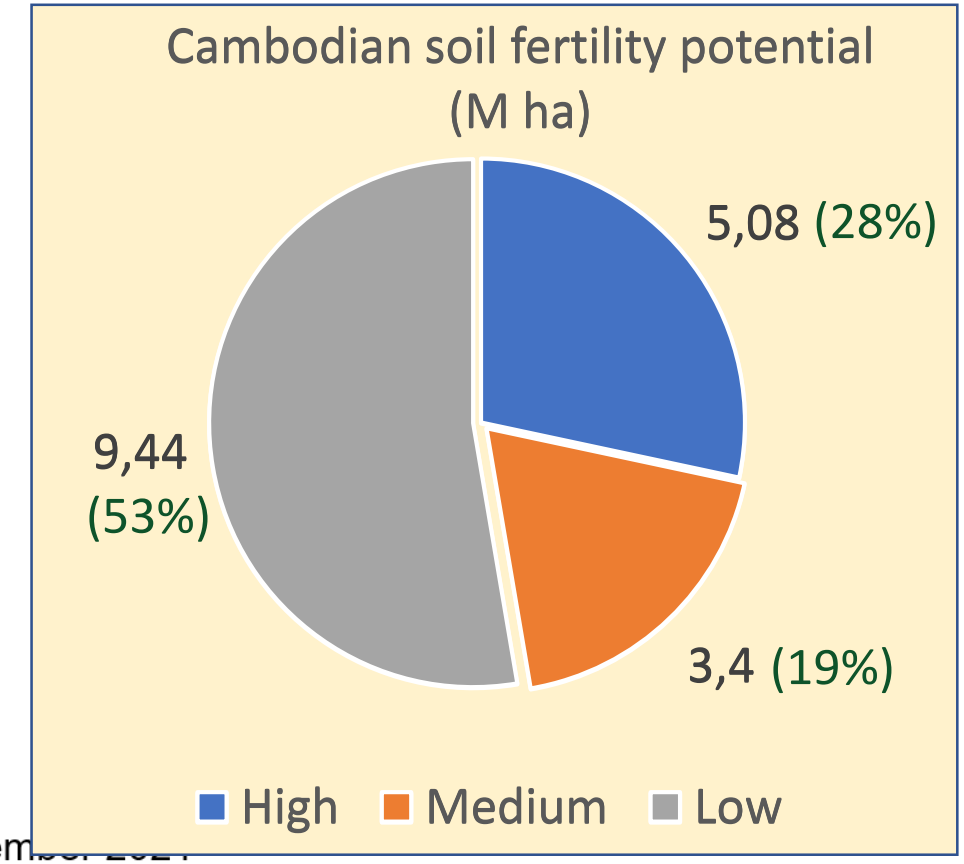


No.	Soils Type	Rainfall (mm)					Total Area (Km2)
		Less than 1700	1700 - 1850	1700 - 2100	2100 - 3100	More than 3100	
1	Acid Lithosols	6,028.25	17,951.83	2,486.19	10,817.75	6,571.78	43,853.803
2	Alluvial Lithosols	8,798.60	4,874.49	890.72	357.81	80.02	15,001.639
3	Alumisols	1,308.86	1,090.33	240.88	382.47	140.82	3,163.363
4	Basic Lithosols	573.89	1,530.99	358.10	750.15	104.87	3,318.000
5	Brown Alluvial Soils	965.86	348.93	2,910.86	..	..	4,225.651
6	Brown hydromorphics	1,758.08	..	..	2,144.55	..	3,902.628
7	Coastal Complex	..	..	228.51	928.36	651.18	1,808.041
8	Cultural hydromorphics	9,795.69	1,107.49	2,969.32	182.73	..	14,055.235
9	Great Lake	2,834.21	1,610.64	945.27	..	..	5,390.119
10	Grey hydromorphics	5,531.09	8,950.10	875.29	1,517.47	138.96	17,012.911
11	Lacustrine Alluvial Soils	8,078.51	78.31	2,288.83	..	..	10,445.656
12	Latosols	1,409.24	3,866.07	276.14	666.49	..	6,307.932
13	Planosols	197.57	..	204.59	1,263.20	..	1,665.364
14	Plinthite podzols	9,450.77	7,492.91	546.98	291.29	..	17,781.950
15	Plinthitic hydromorphics	..	1,161.77	..	..	..	1,161.773
16	Red-yellow podzols	10,093.56	6,359.81	4,755.63	2,852.56	1,381.39	25,442.947
17	Regurs	1,655.11	3,897.73	391.64	347.22	..	6,291.704
18	No Classify	113.3205	376.2652	70.862873	113.1026	104.4611	778.012
	Total Area (Km2)	68,680.61	60,697.67	20,439.82	22,615.14	9,173.49	181,606.729

- 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%)**

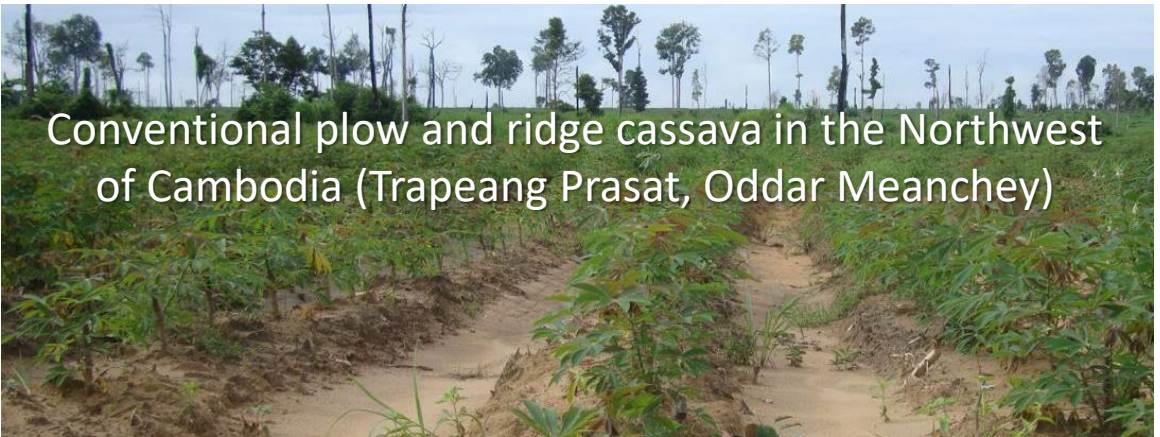


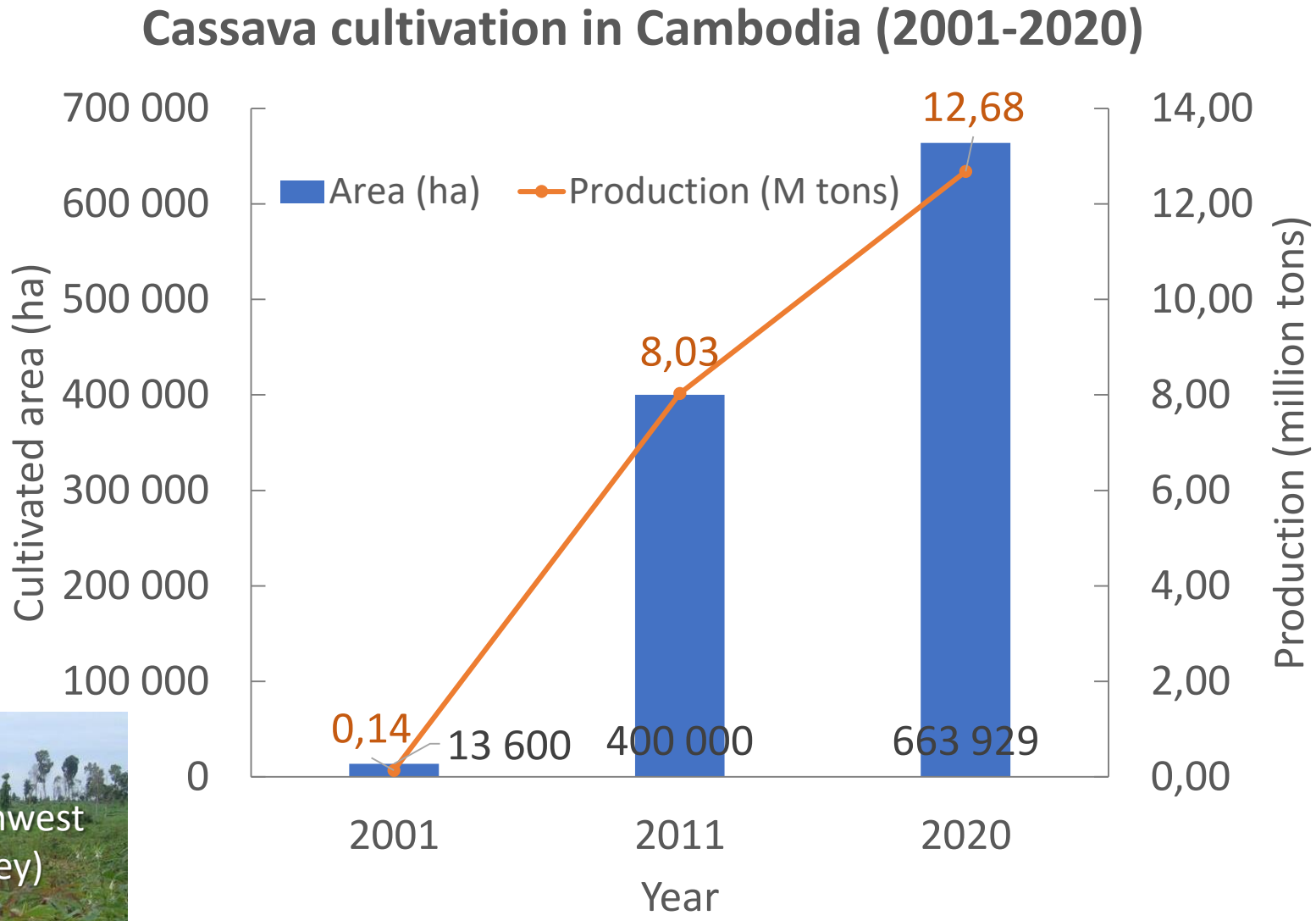
Cambodian Agricultural Land Use

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)





National average yield in 2020 (fresh tuber) ≈ **18** tons/ha (CDC, 2021)

Status of Cambodian soil and natural resources

Current issues:

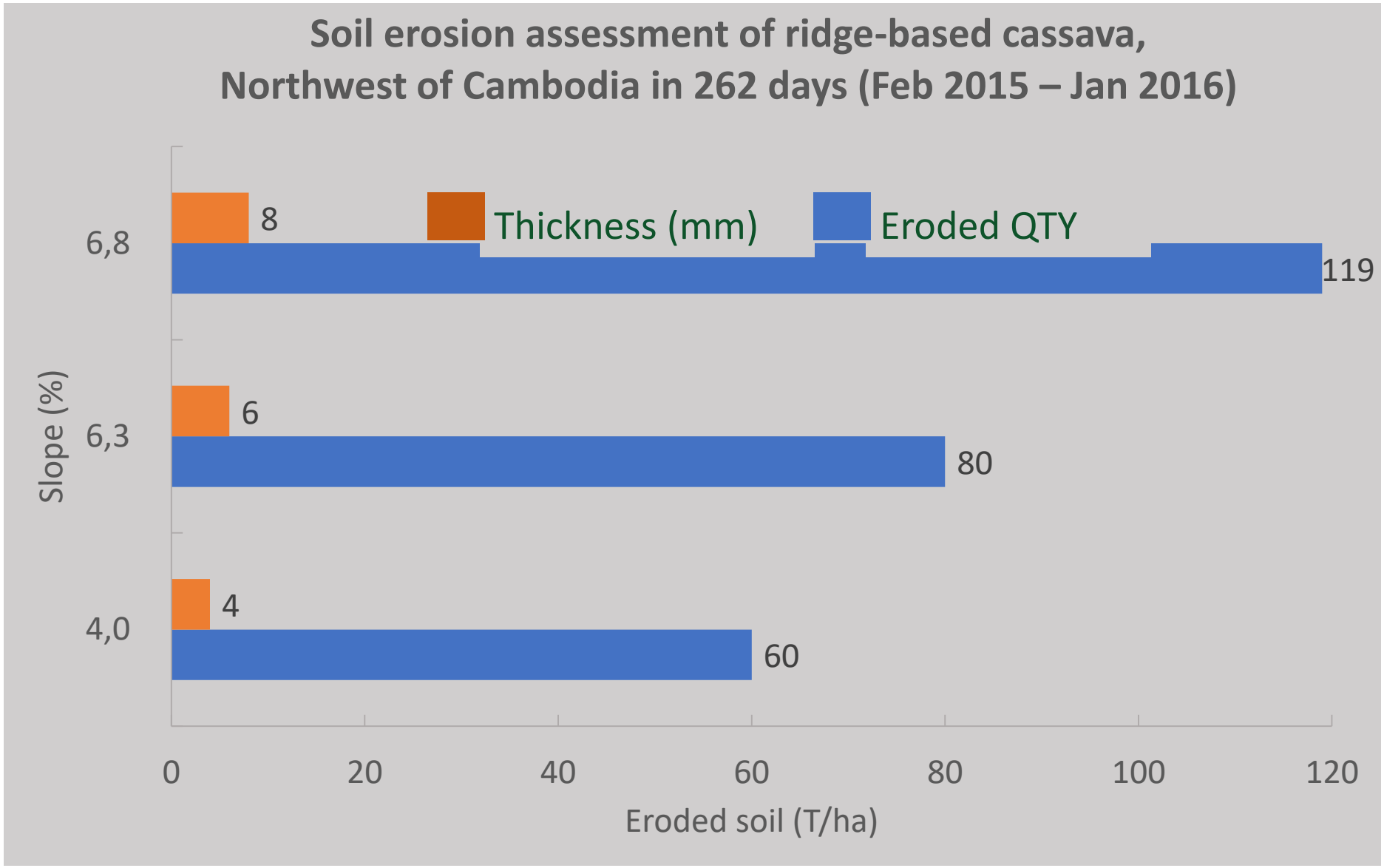
- Soil erosion
- Imbalance of soil quality (huge removing > returning)
- Loss of biodiversity and abundances
- Erratic rainfall patterns (climate change)
- Pollution caused by inappropriate uses of agro-chemicals

… maize and cassava production for animal feeds and biofuel …

Land degradation affects 78,000 km^2 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



CARDI, 2017 (IDM project)

Roles of Soil Organic C on Soil Quality and Soil Health

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)

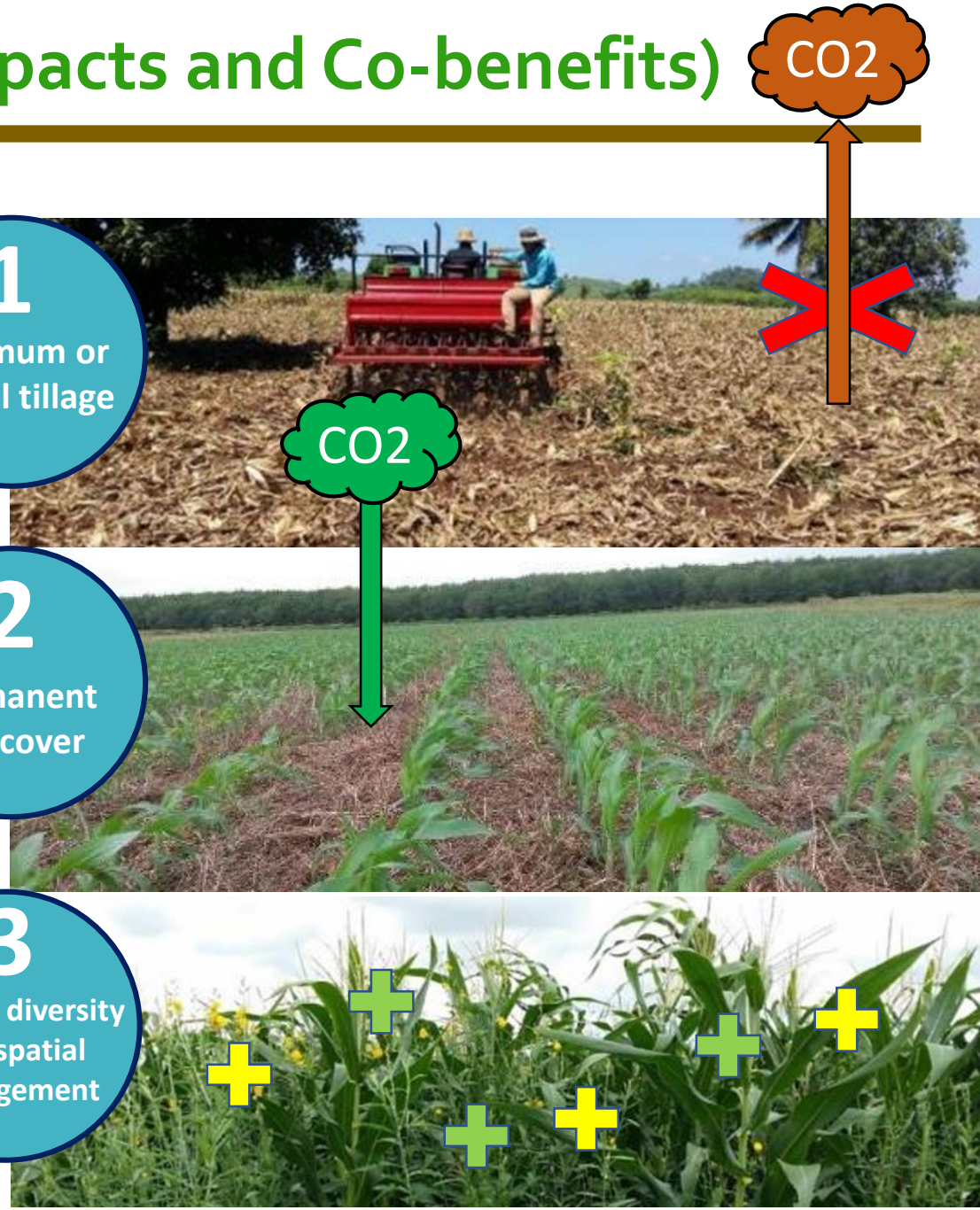
- Yield improvement and resilience (Food security and increase livelihood)

- Biodiversity and environment conservation

Carbon emissions reduction

Carbon sequestration

Enhance biodiversity



Research Objectives

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.

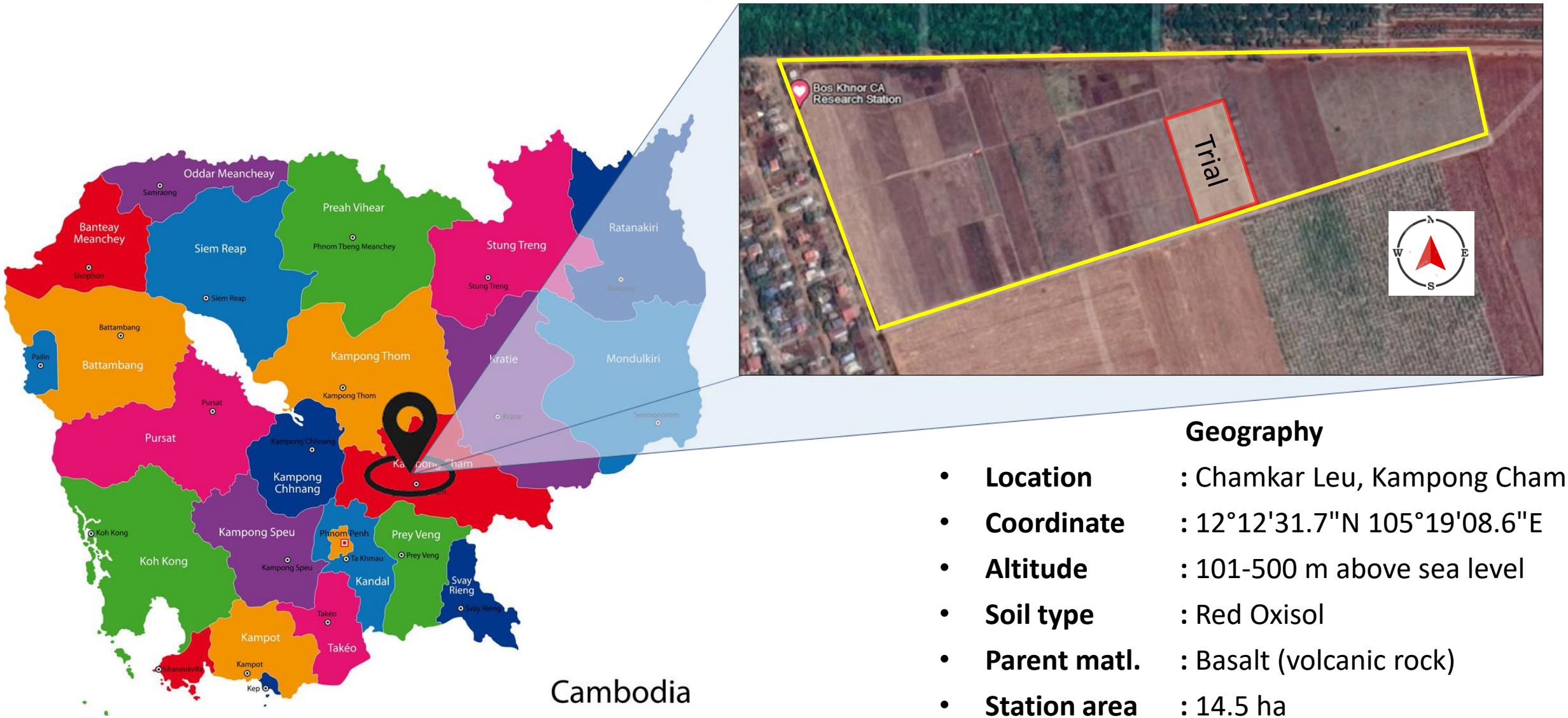
The **specific objectives** are to assess the changes in:

(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.

Research Station Location



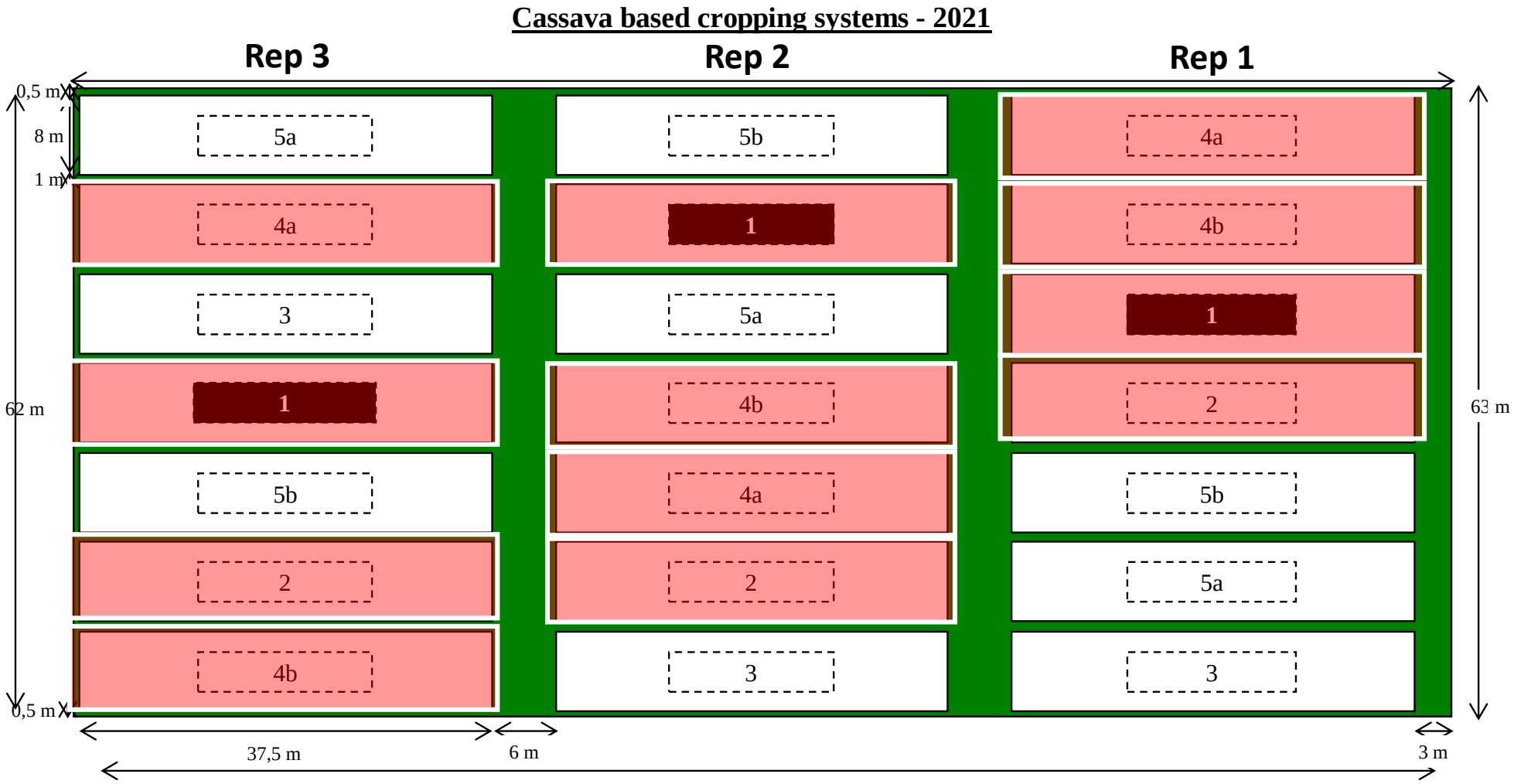
Cambodia

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

Experimental Design

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 3,600m^2.



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 3,600m^2.

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 (*Stylosanthese 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

- Biopump: (0-0-30)

  KCl 50 kg/ha 30 DAS
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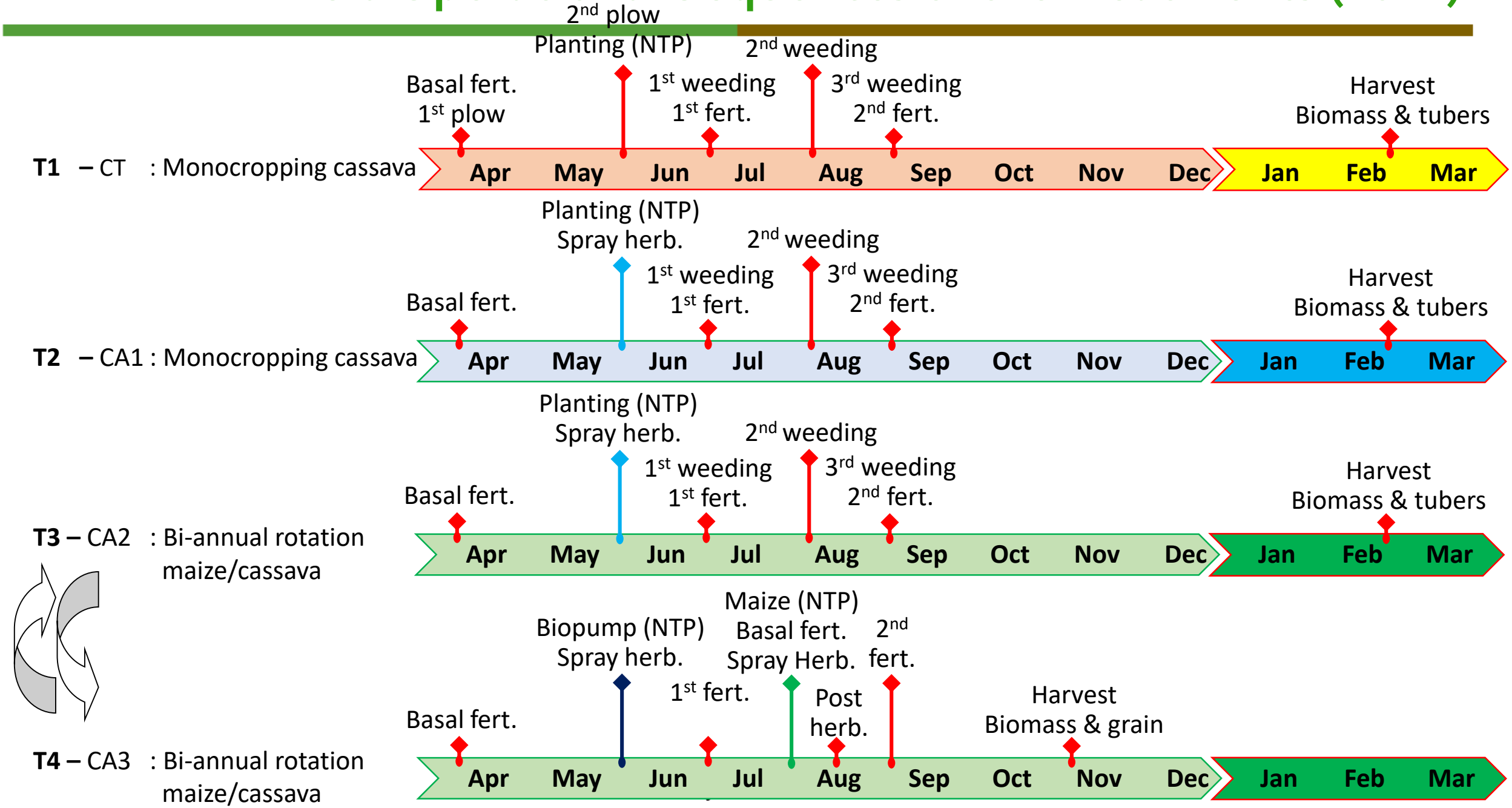
  KCl 50 kg/ha 30 DAP

  Urea 50 kg/ha 30 DAP

  KCl 50 kg/ha 90 DAP

  Urea 50 kg/ha 90 DAP

Field Operational Sequences of the Treatments (2021)

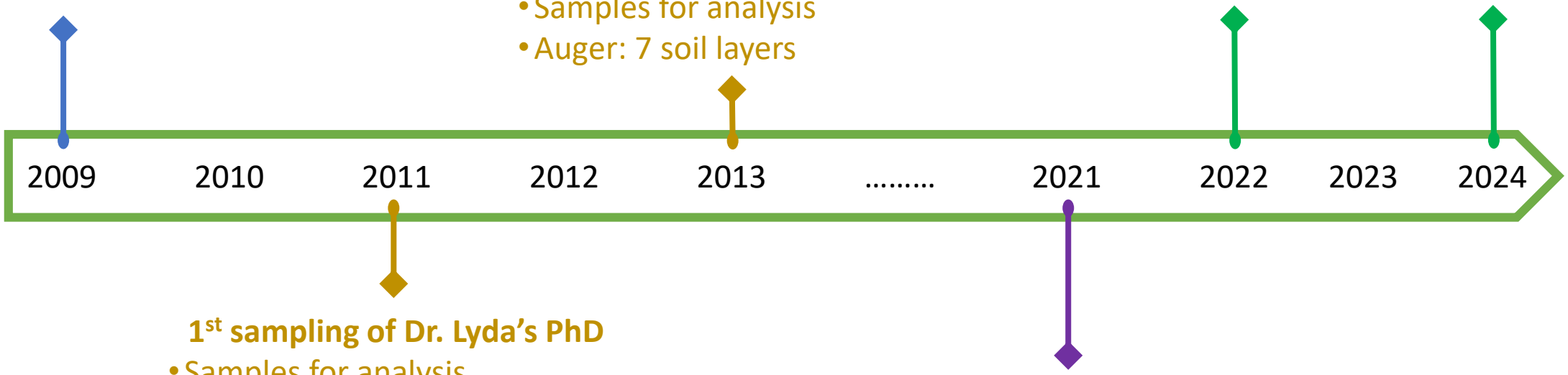


Timeline: Experiment & Diachronic Samplings

Expr. establishment
- Pre expr. sampling

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

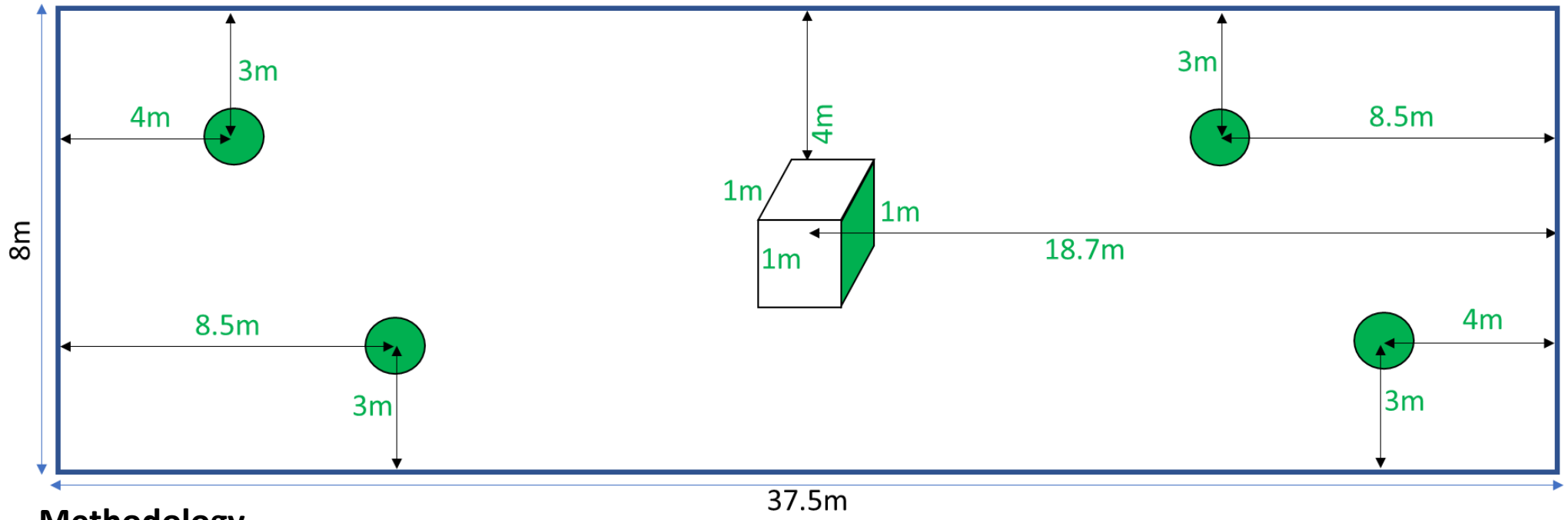
GHGs sampling of Vira's PhD
- 2 years: April, 2022 - Feb, 2024
- Closed chamber

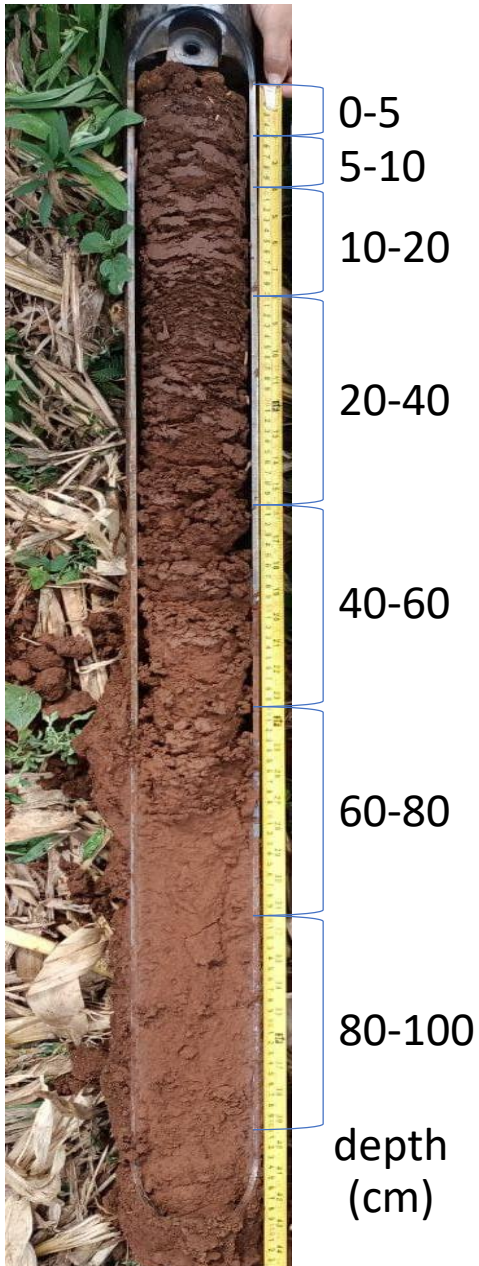


1st sampling of Dr. Lyda's PhD
- Samples for analysis
- Bulk density
- Aggregate samples
- Open soil pits: 7 soil layers

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

Soil Sampling Pattern in 2021 (Pit + Auger)





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 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**

Soil Samples Processing and Preparation

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

Particle Size Fractionation and Nature of SOC Stability

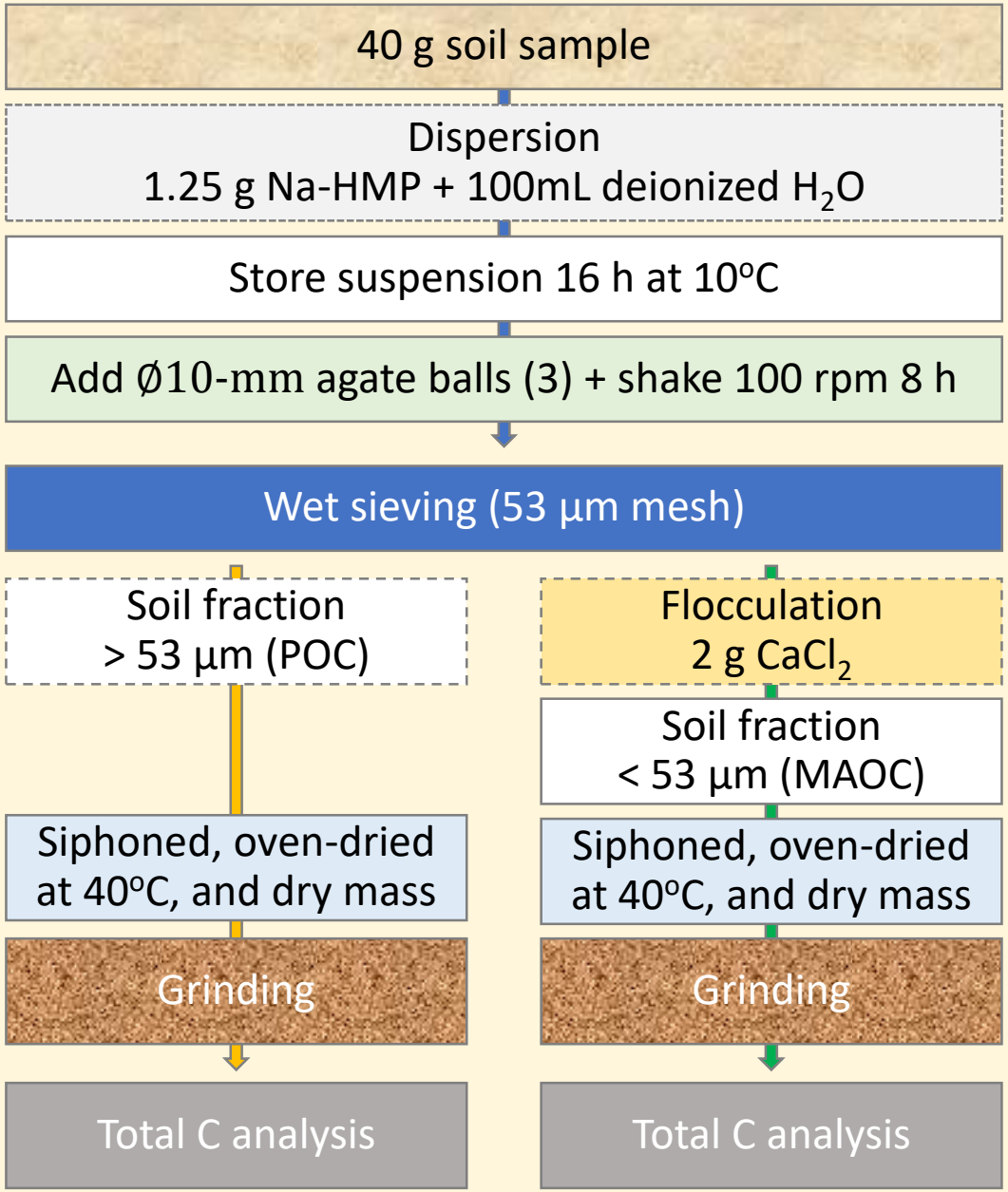
Associations between soil particles and their special arrangement are important for SOC dynamics

- **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° 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



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

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 deployed per elementary plot to collect the GHGs (CO_2, CH_4, and N_2O) 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