Laboratoire de Biomathématiques & d'Estimations Forestières

Global Taxonomy Initiative

Capacities for Biodiversity and Sustainable development

Institut Royal des Sciences Naturelles de Belgique

Research project

Use of Soil-litter Arthropods as Biological Indicators of Soil Quality in Southern Rwanda

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Introduction

Soil

Soil Quality

A Habitat for soil biodiversity:
- Fungi, algae, bacteria, protozoa
- Invertebrates with 85% being soil and litter arthropods

Soil Fauna

Functions

- Soil structure through aggregation of soil particles & microbial activities
- Mixing of soil particles, galleries creation, pores, tunnels: water flow and soil respiration
- Organic matter decomposition, nutrient cycling & availability of soil nutrients to plant diversity

Soil Fauna and Soil Properties

Capacity of a specific soil to function within natural or managed ecosystem boundaries to sustain animal and plant productivity, maintain or enhance water and air quality and support human health

Regulators

- Integral component of ecosystem processes and biogeochemical cycles
- Key resource for agriculture production
- Source of nutrients for plant growth

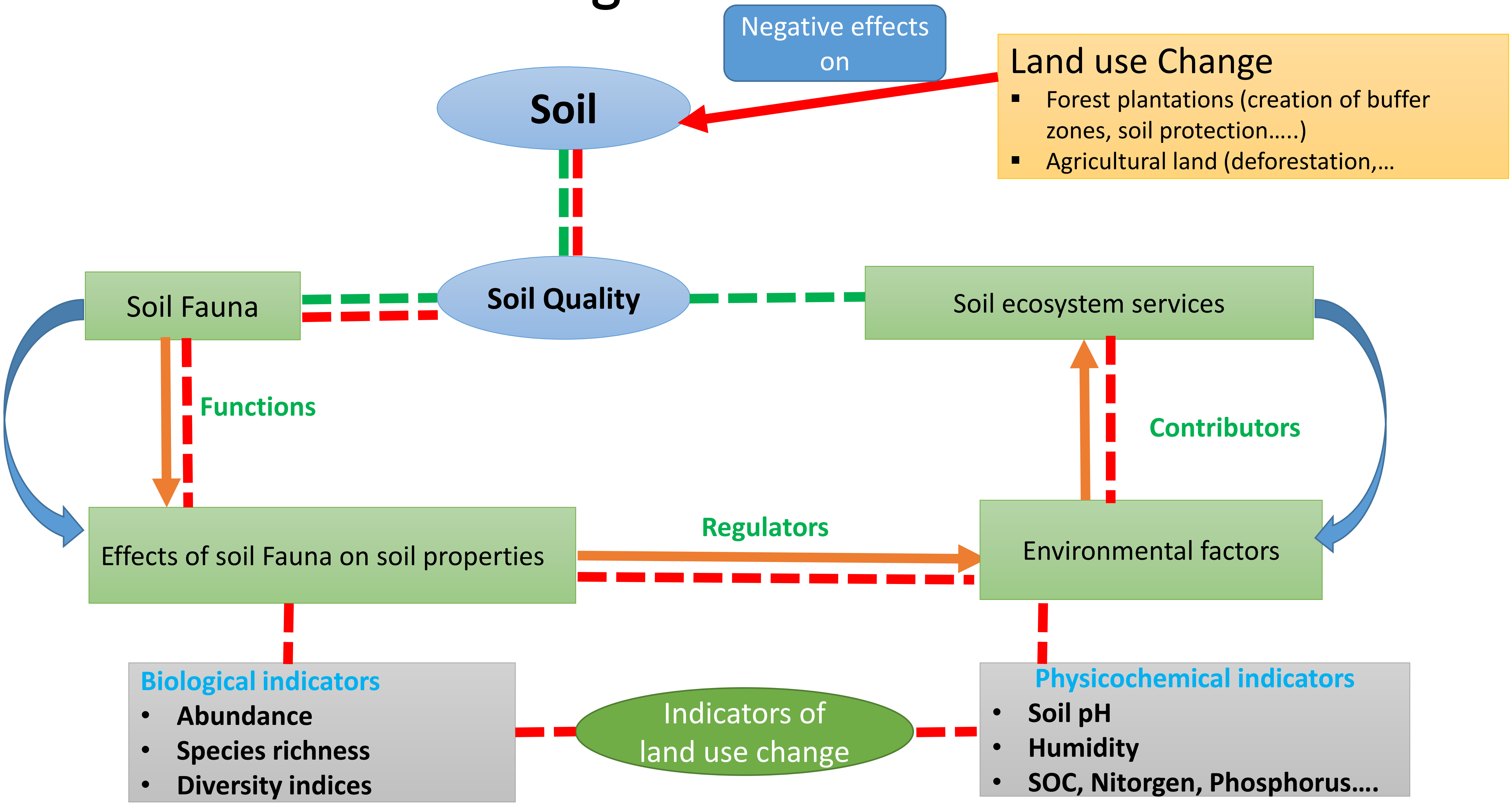
Soil ecosystem goods and services

Contributors

Environmental factors: Climate, temperature, soil texture, nutrients, pH, water availability….

Environmental factors

Soil and Land Use Change



?

- Is the land use change the only one factor driving changes in Abundance, Species richness & Diversity indices
- How soil and litter arthropods are used as biological indicators?
- Which groups of soil and litter arthropods are concerned?

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Use of soil and litter arthropods as biological indicators of soil quality in forest plantations and agricultural lands: A Review

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This article reviewed published papers on the use of soil and litter arthropods as biological indicators of soil quality since the 1970s. Our review shows that soil and litter arthropods are litter transformers and ecosystem engineers. They contribute to the availability of organic matter. Their diversity, abundance, biomass, and density are suitable measures for the assessment of natural and/or anthropogenic effects on soil. However, their use is challenged by difficulties in sampling methods and the identification of soil and litter arthropod diversity up to species level, and few research projects combine both abiotic and biotic factors. We recommend further research to investigate the most suitable methods for sampling soil and litter arthropods, and create a classification of dominant groups up to species level which, along with the use of integrative methodologies, will be valuable steps towards a generalized and accepted method for the assessment of soil quality.
Key words: arthropods, soil quality, indicator, forest plantations, agricultural lands.

1. A Comparative Study Between Sampling Methods for Soil Litter Arthropods in Conserved Tree Plots and Banana Crop Plantations

Hand sorting

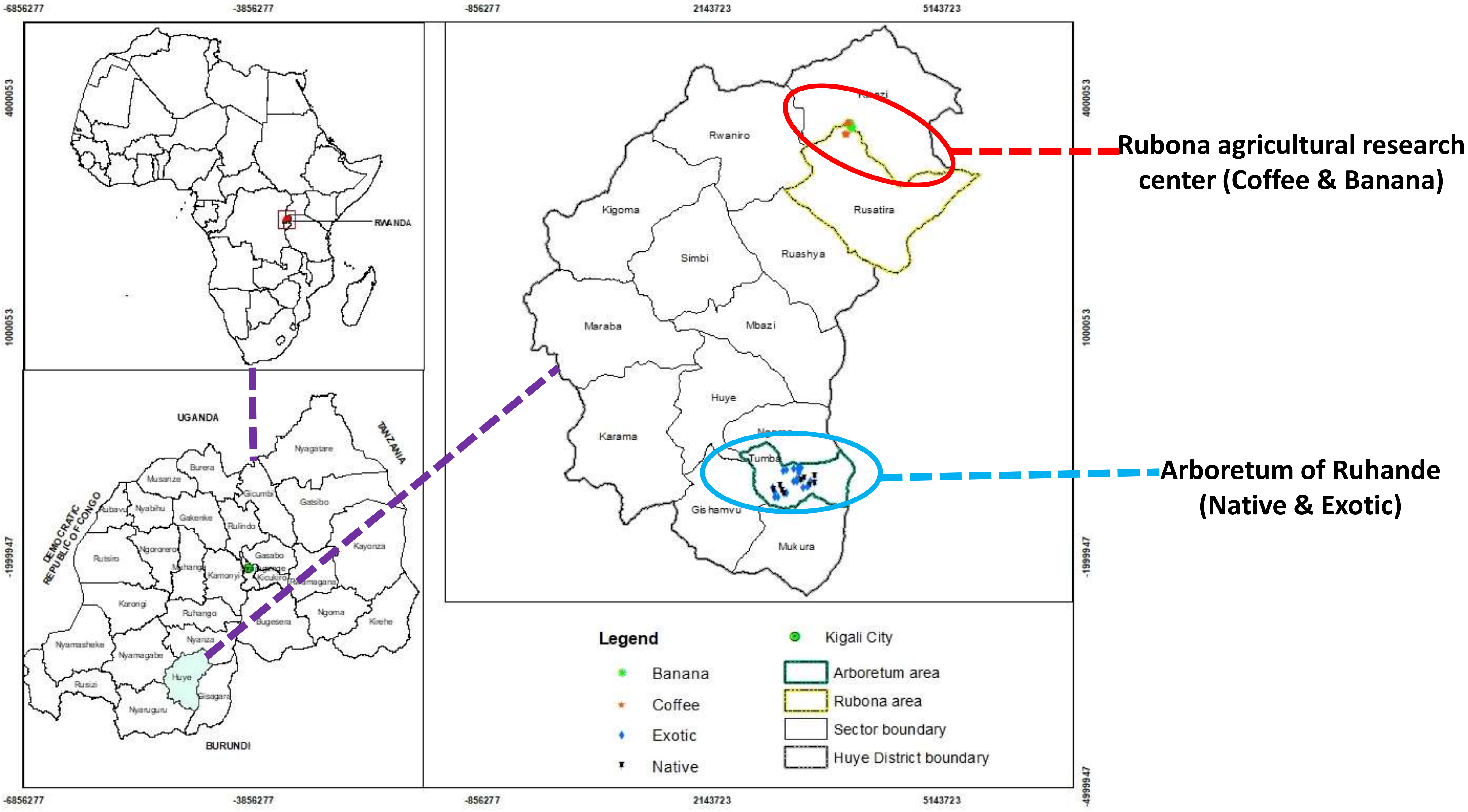
Pitfall

Berlese – Tullgren Funnels

Forest tree species (*P.fulva, G.Robusta, E. Maideni & C.serata*)

Varieties of banana plantations (Mporogoma, Injagi, FHIA17& FHIA25)

Varieties of coffee plantations (HARRAR, JACKSON & RABC15)



Rubona agricultural research center (Coffee & Banana)
Arboretum of Ruhande (Native & Exotic)
RWANDA
UGANDA
TANZANIA
DEMOCRATIC REPUBLIC OF CONGO
BURUNDI
Nyagatare
Burera
Musanze
Gicumbi
Gatsibo
Rubavu
Nyabihu
Gakenke
Rulindo
Rutsiro
Ngororero
Gasabo
Kayonza
Muhanga
Kamonyi
Kicukiro
Rwamagana
Karongi
Ruhango
Ngoma
Bugesera
Kirehe
Nyanza
Nyamasheke
Nyamagabe
Huye
Rusizi
Gisagara
Nyaruguru
Rwaniro
Rusatira
Kigoma
Simbi
Ruashya
Maraba
Mbazi
Huye
Karama
Tumba
Gis hamvu
Muk ura
Legend
Banana
Coffee
Exotic
Native
Kigali City
Arboretum area
Rubona area
Sector boundary
Huye District boundary
-6856277
-3856277
-856277
2143723
5143723
4000053
1000053
-1999947
-4999947

A comparative study between sampling methods for soil litter arthropods in conserved tree plots and banana crop plantations in Rwanda

International Journal of Development and Sustainability

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Abstract

The aim of this study was to compare trapping efficiency between Berlese-Tullgren funnels, pitfall traps and hand sorting sampling methods for soil litter arthropods. The study was carried out at the Arboretum of Ruhande and Rubona agricultural research station, in southern Rwanda. Biological indices indicated that pitfall traps collect a wide range of soil litter arthropod diversity, and chi-square test indicated the dependence between Berlese-Tullgren funnels and pitfall traps, and between pitfall traps and hand sorting. Z-test and univariate comparison indicated differences in means between tested sampling methods. The analysis of variance revealed that pitfall traps are less time consuming and the principal component analysis indicated that Formicidae is likely to be collected by pitfall traps and Berlese-Tullgren funnels, while Julidae, Porcellionidae and Geophilidae are likely to be collected by hand sorting. Research concluded that pitfall traps are more efficient than other studied sampling methods, but further studies should be conducted in other ecological zones, and different land uses in order to generate general information of these findings.

Keywords: Efficiency; Efficient; Meantime; Diversity; Evenness

2. Identification of dominant family of soil and litter arthropods and Its relationship with physicochemical parameters

General objective:

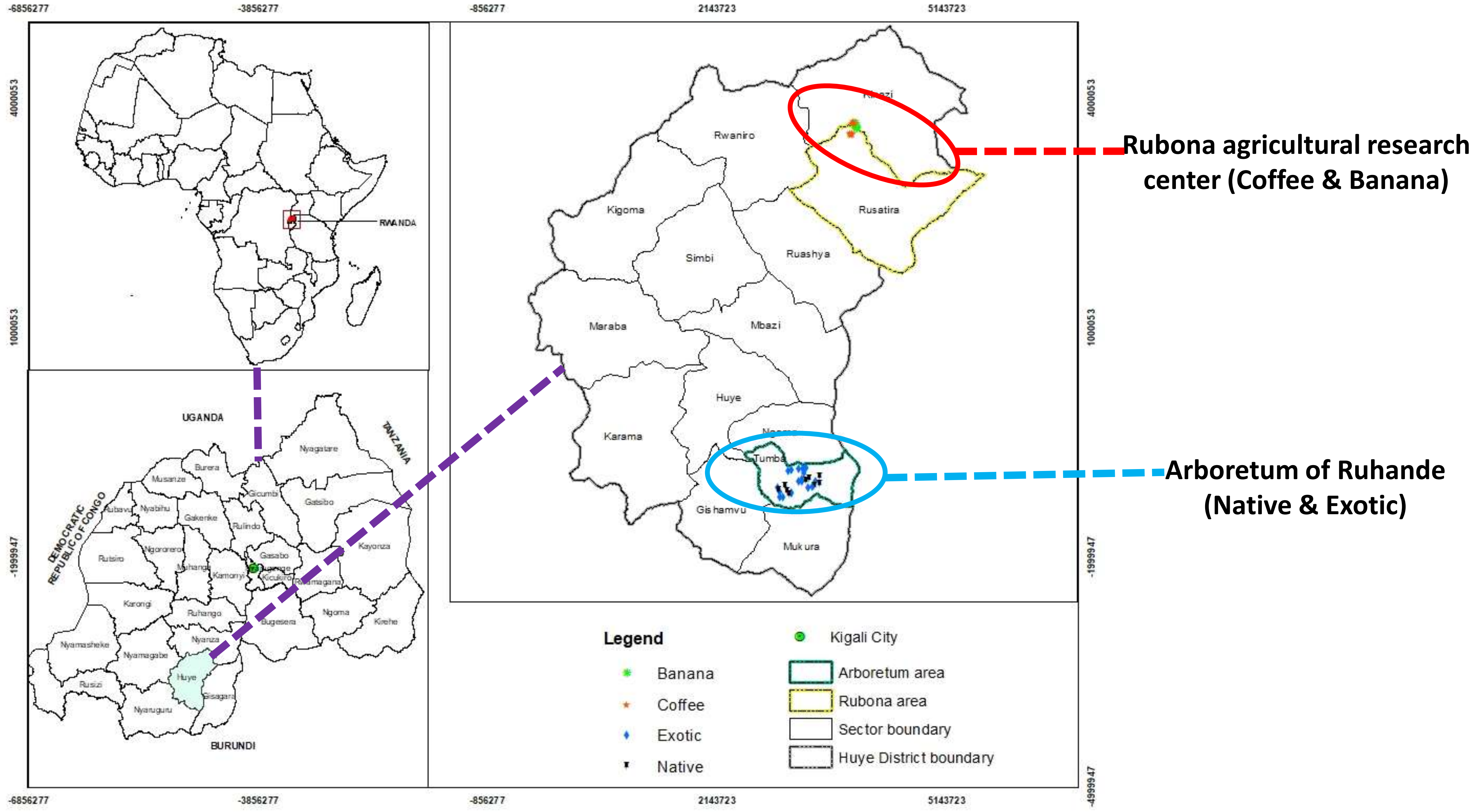
Examine and compare the influence of different land uses on the diversity and abundance

Specific objectives:

- Examine and compare the diversity, abundance, and evenness of soil litter arthropods under dominant tree species, Coffee and Banana plantations
- Examine the variation of soil physicochemical parameters in each land use (forest and crop plantations)
- Study the relationship between biological (the diversity, evenness and abundance) and physicochemical parameters (Soil pH, total nitrogen, soil organic carbon, C:N ration, CEC, EC, AS, available phosphorus and texture

In addition: → Ecological functions of identified soil and litter arthropods was documented in the literature and were used to determine the contribution of soil and litter arthropods to sil properties

Hypothesis: → Positive correlation between soil and litter arthropods and soil physicochemical parameters is associated to the ecological functions that soil and litter arthropods exert on soil



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Rutsiro
Ngororero
Gasabo
Kayonza
Muhanga
Kamonyi
Kicukiro
Rwamagana
Karongi
Ruhango
Ngoma
Bugesera
Kirehe
Nyanza
Nyamasheke
Nyamagabe
Huye
Rusizi
Gisagara
Nyaruguru
Rwaniro
Kinazi
Kigoma
Rusatira
Simbi
Ruashya
Maraba
Mbazi
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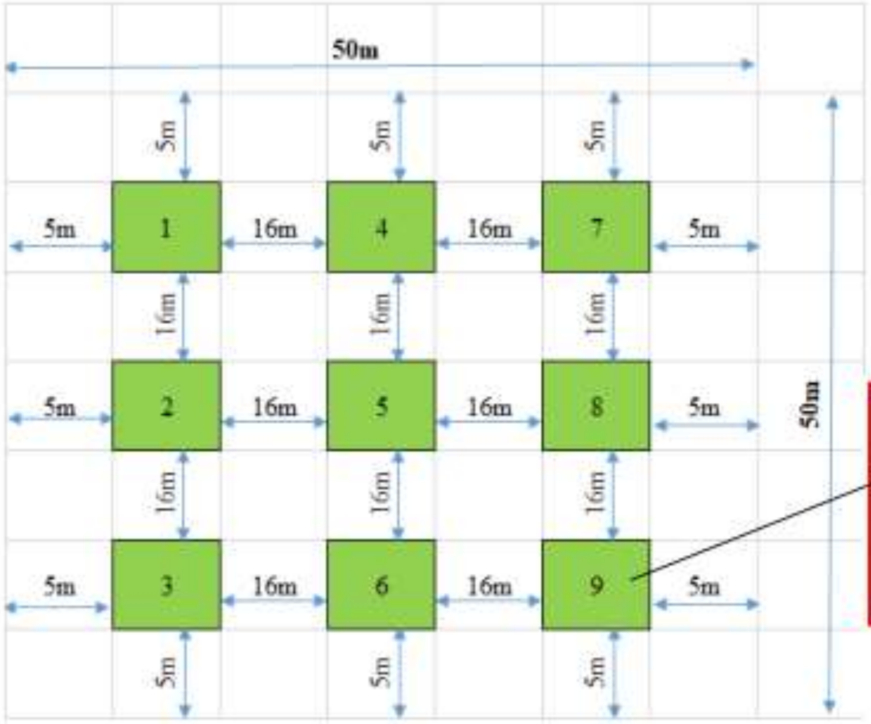
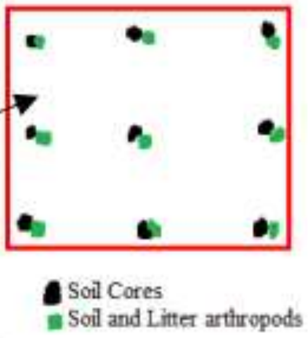
4000053
1000053
-1999947
-4999947

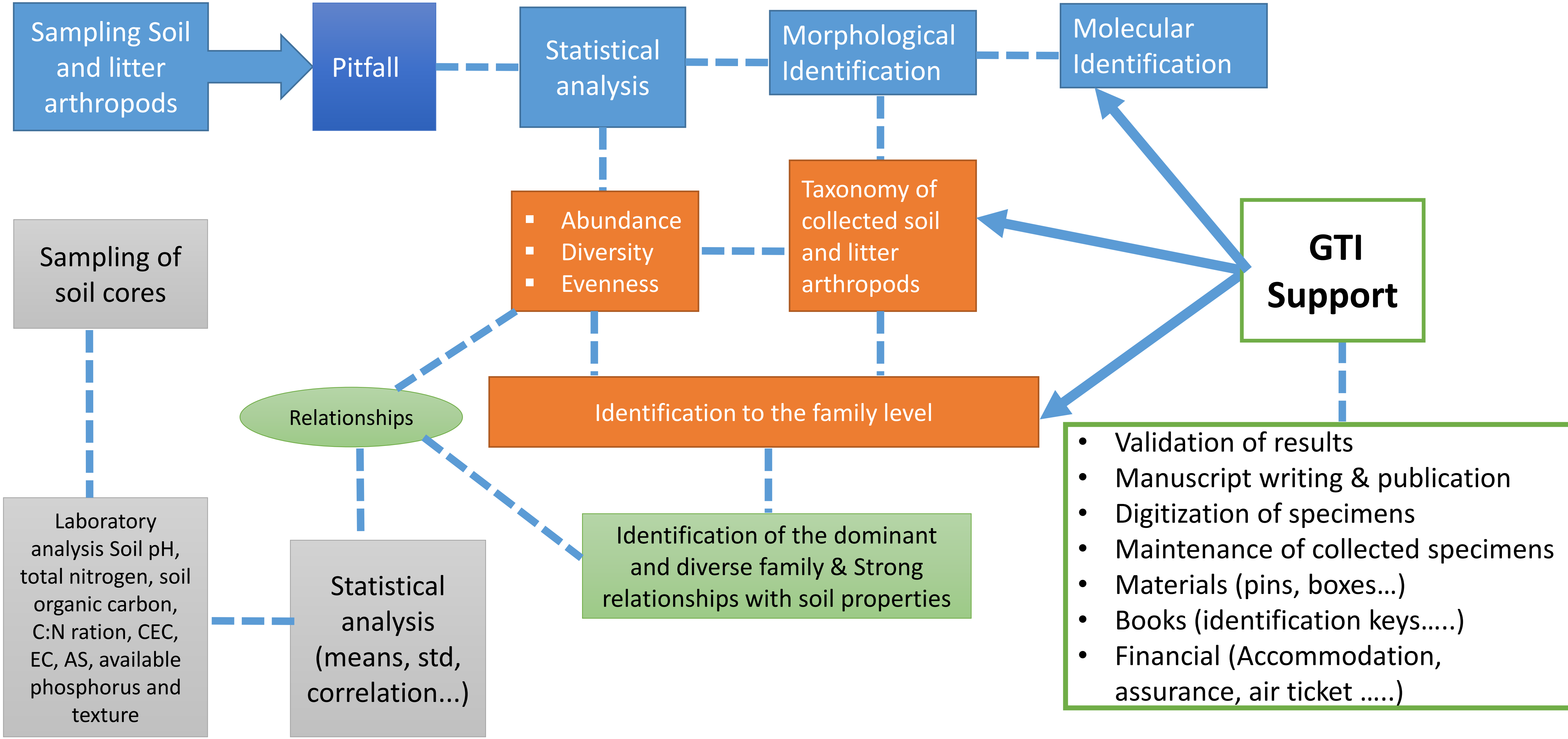
Sampling Design

- Each land use was replicated three times in 50x50m
- 9 sampling points were selected for sampling soil-litter arthropods and soil cores





Data Analysis



Results

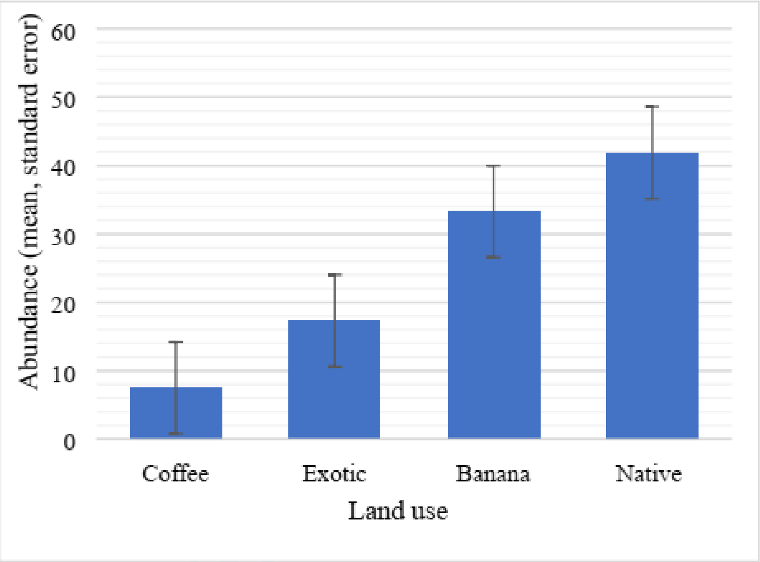


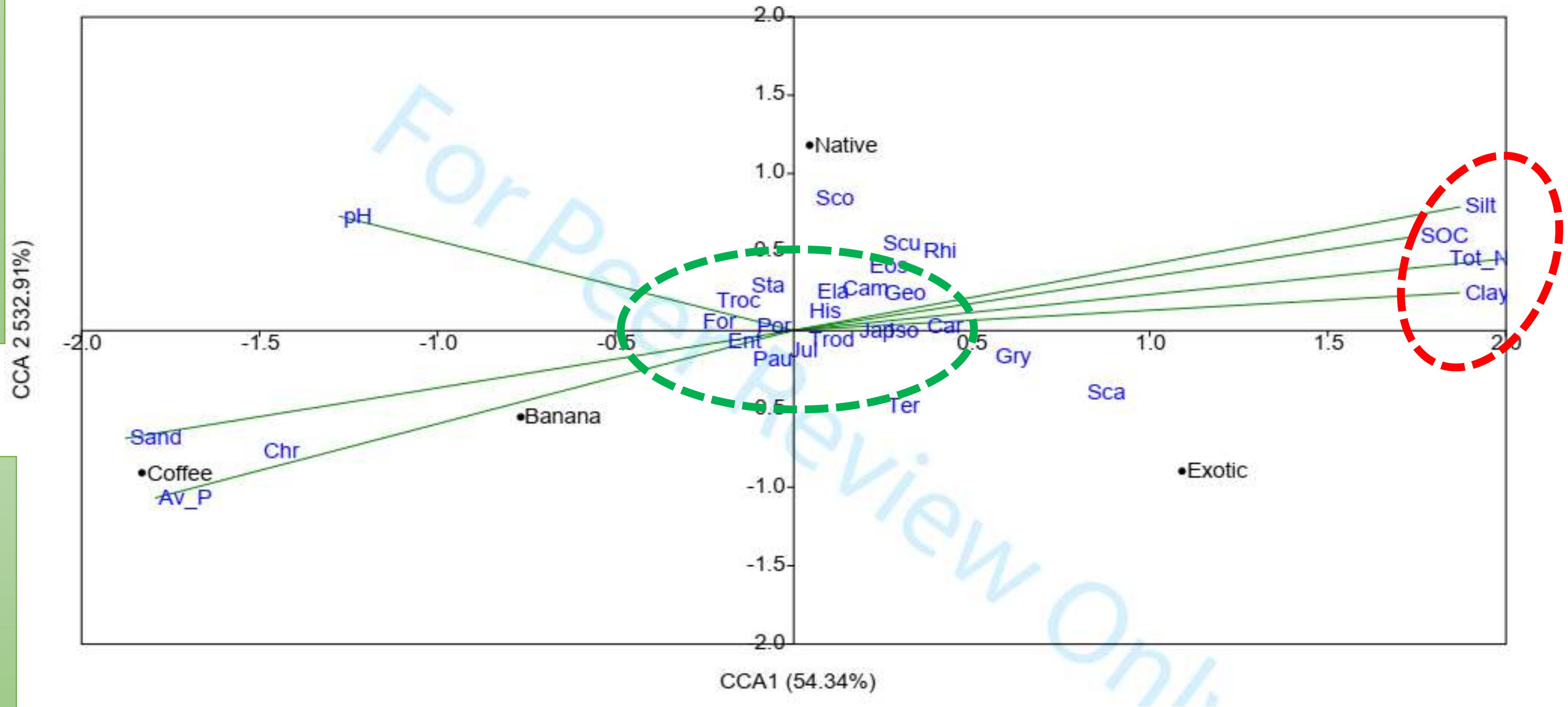
Table 3: variations in soil physicochemical properties (mean ± standard deviation) under different land uses (SOC: soil organic carbon, Tot. N: total nitrogen, Av. P: available phosphorus)

Land use	Soil pH	SOC (%)	Tot. N (%)	Av. P (mg/Kg	Clay (%)	Silt (%)	Sand (%)
Exotic	5.3 ± 0.3	7.6 ± 2.9	0.6 ± 0.3	4.0 ± 1.4	13.7 ± 2.2	16.4 ± 2.1	68.9 ± 3.9
Native	6.1± 0.5	6.4 ± 0.2	0.5 ± 0.1	3.7 ± 0.9	14.6 ± 4.4	17.5 ± 2.8	69.0 ± 0.7
Banana	6.1± 0.5	2.6 ± 0.7	0.4 ± 0.2	13.7 ± 0.8	12.1 ± 1.5	11.7 ± 1.5	75.7 ± 2.5
Coffee	5.8 ± 0.4	3.3 ± 0.	0.3 ± 0.1	15.5 ± 0.3	12.7 ± 2.0	11.0 ± 3.0	76.3 ± 3.2

Diversity indices

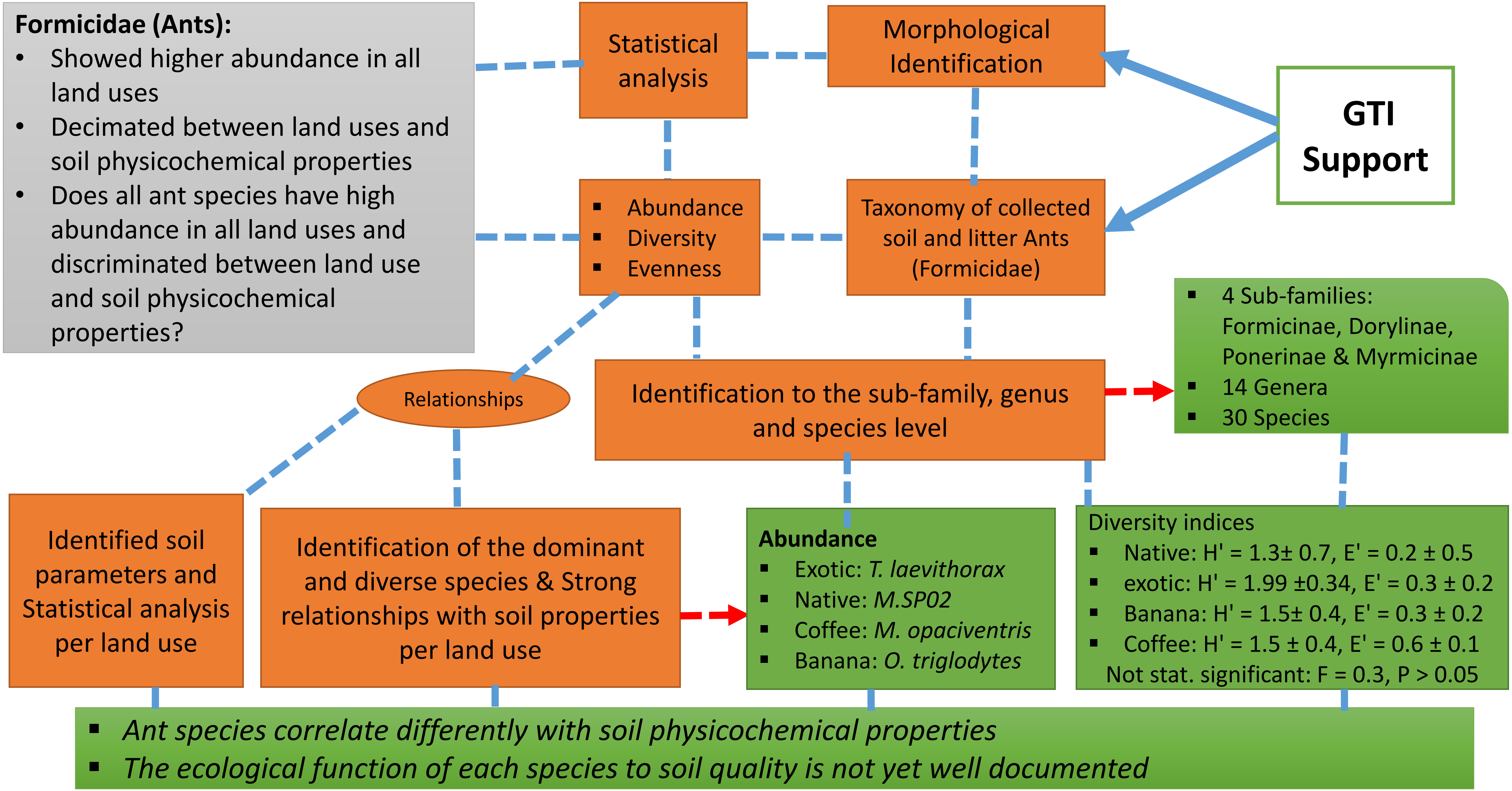
- Native: **H' = 2.5± 0.1**, E' = 1.2 ± 0.1
- exotic: **H' = 1.7 ± 1.1**, E' = 0.9 ± 0.3
- Banana: H' = 1.2± 1.0, **E' = 1.3 ± 0.2**
- Coffee: H' = 0.8 ± 0.3, **E' = 1.4 ± 0.2**

Stat. significant: F = 1.1, P = 0.03, 95%



Land use, ecological functions & Soil physicochemical properties

The ecological functions that contribute to soil quality are known for some order and some families


Formicidae (Ants):
Showed higher abundance in all land uses
Decimated between land uses and soil physicochemical properties
Does all ant species have high abundance in all land uses and discriminated between land use and soil physicochemical properties?
Statistical analysis
Morphological Identification
GTI Support
Abundance
Diversity
Evenness
Taxonomy of collected soil and litter Ants (Formicidae)
4 Sub-families: Formicinae, Dorylinae, Ponerinae & Myrmicinae
14 Genera
30 Species
Relationships
Identification to the sub-family, genus and species level
Identified soil parameters and Statistical analysis per land use
Identification of the dominant and diverse species & Strong relationships with soil properties per land use
Abundance
Exotic: T. laevithorax
Native: M.SP02
Coffee: M. opaciventris
Banana: O. triglodytes
Diversity indices
Native: H' = 1.3± 0.7, E' = 0.2 ± 0.5
exotic: H' = 1.99 ±0.34, E' = 0.3 ± 0.2
Banana: H' = 1.5± 0.4, E' = 0.3 ± 0.2
Coffee: H' = 1.5 ± 0.4, E' = 0.6 ± 0.1
Not stat. significant: F = 0.3, P > 0.05
Ant species correlate differently with soil physicochemical properties
The ecological function of each species to soil quality is not yet well documented

Conclusion

- Community composition of soil and litter arthropods can differently correlate with soil physicochemical parameters
- Functional groups soil and litter arthropods can indicate the status of the soil where they have been collected
- The positive correlation might be explained by ecological functions of soil and litter arthropods which are:
  - ✓Known for some families,
  - ✓Generalized to orders for some other families,
  - ✓Remain unknown for species of soil and litter ants
- There is a high decreasing in soil and litter arthropod diversity and abundance from native tree species to exotic tree species and to the varieties of coffee and banana plantations. This allows us to conclude that:
  - ✓There is an important role of native tree species in conservation of soil and litter arthropods.
  - ✓Some exotic tree species and varieties of coffee plantations can provide alternative suitable habitat for some soil and litter ant species.

Future Direction

Future studies may explore:

(1) The use of soil and litter arthropods as biological indicators of soil quality in other land uses and ecological regions of Rwanda

(2) The impacts of climate and altitudinal variations in soil and litter arthropods and soil physicochemical parameters

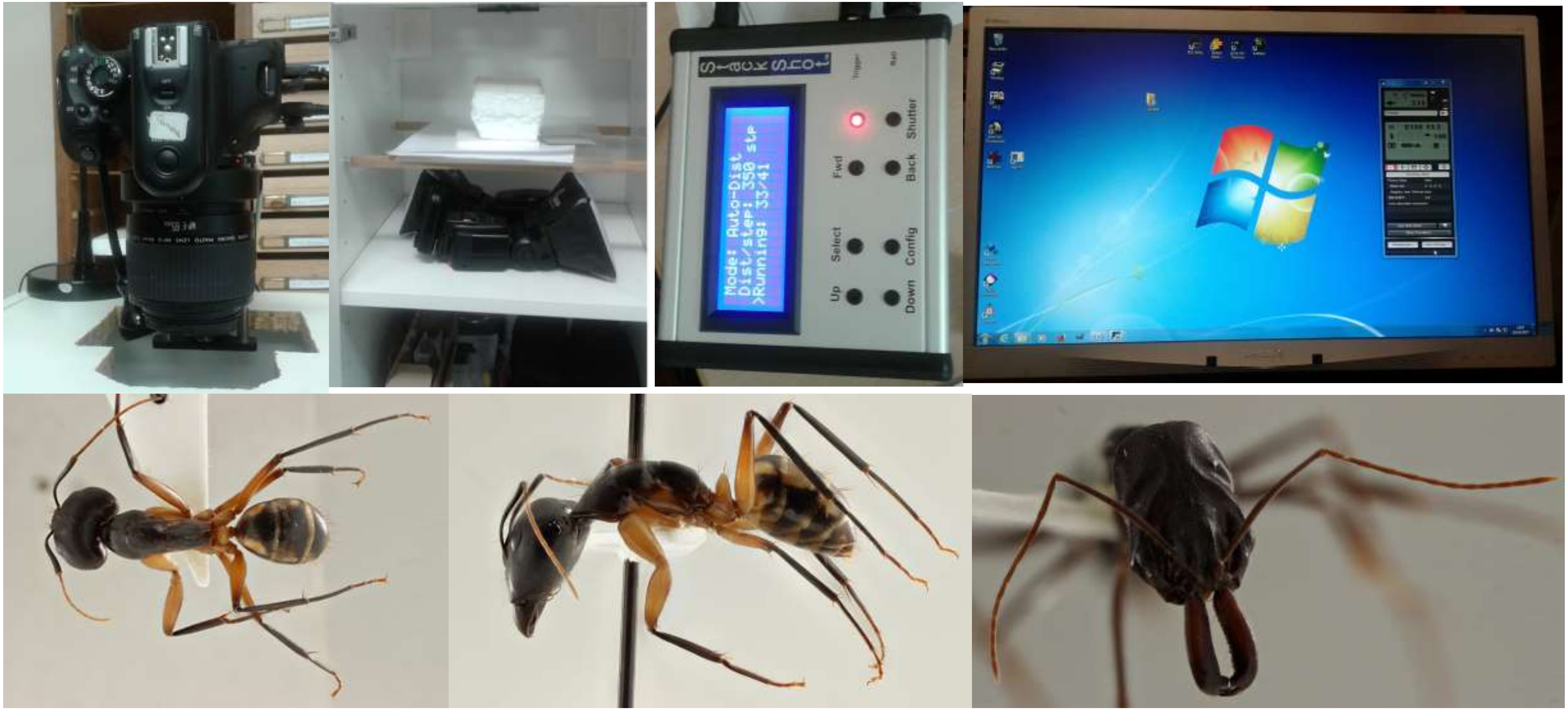
(3) Investigate the variation of soil-litter arthropods in relation to soil metals and soil biochemistry

(4) The impacts of functional richness, functional evenness and functional divergence on primary components of functional diversity

(5) Levels of disturbances that can affect exotic and naïve tree species and varieties of coffee and banana plantations

(6) The taxonomy of the community composition to species level

Collaborative work with international research supported by GTI-CEBios, October 2017



Materials used for digitization of collected specimens of Ants , October 2017

The identification work started in October 2017 was completed in October 2018. Samples are stored at the Museum of the RBINS, Belgium and at The CoEB – UR-CST, Rwanda

Thesis Public Presentation and Award of PhD Degree in Agronomy and Bioengineering, November 2018

Taxonomy Training and Capacity building Training in Manuscript Writing and Publication, October 2019



Thank You