Title: **" The Ni biogeochemical cycle in a tropical agromine metal crop system: c***onsequences of the exhaustion of available soil Ni pool due to sustained harvesting”*

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Key-words: Agronomy, Soil science, Mineral resources, Strategic metals, Biogeochemical cycling, phytomining

State of the Art:

The research on nickel isotope geochemistry in ultramafic ecosystems undertaken by Nicolas Estrade (post-doctoral research funded by LabEx R21) unambiguously demonstrated that plants, specifically hyperaccumulator plants, directly influence the composition of available and total Ni pools in ultramafic soils. The results of this work generated the following hypothesis: *plants, and particularly Ni hyperaccumulator plants, play a major role in maintaining high concentrations of Ni in the surface of soils during weathering and pedogenesis*. Hence, agromining ultramafic soils will necessarily deplete the plant generated Ni-reservoir.

In natural tropical ultramafic soils, or in saprolite mine wastes, the pool of available Ni will be strongly depleted by hyperaccumulator plants and biogeochemically recycled or withdrawn from the ecosystem by harvested biomass. Currently, there is no information on the dynamics and quantification of the Ni pools in ultramafic soils and therefore the potential duration and the efficiency of agromining. Moreover, there are additional fundamental questions that arise, including the ecological role (niche) of hyperaccumulator plants in native ultramafic ecosystems, their role in ultramafic pedogenesis, and the efficiency of biogeochemical cycling (nutrients and metals) in hyperaccumulator plant stands. In the frame of the ‘Nickel’ Project (2014–2017), LabEx Ressources21 funded experiments aimed at characterising the nutrient requirements of two candidate ‘metal crop’ species from south-east Asia. This project comprised of a large randomised-block dosing trial, and a fully characterised 1.5-ha agromining plot. The latter is situated on ultramafic Cambisols which are similar to many saprolite mine wastes (*e.g.* have similar physico-chemical characteristic, including the Ni-bearing phases). This work, and the experimental design, provide an ideal opportunity to address both fundamental and applied aspects of the earlier mentioned scientific questions.

Objectives:

Agromining is an integrated chain that aims at producing commercial metal salts (*e.g.* Ni) from native hyperaccumulator plants ('metal crops') on either mineralised (ultramafic) soils or mine wastes. The annual yield of Ni production is at least 100 kg Ni ha^{-1} yr^{-1} using herbaceous species (such as *Alyssum* spp.) in temperate regions. In tropical regions, most Ni hyperaccumulator plant species are species and are likely able to extract even more Ni per year (preliminary evidence from Philip's Nkrumah's PhD Project suggests >300 kg Ni ha^{-1}). As a consequence, in the native habitat, trpoopical hyperaccumulator species are responsible for a high turnover of hyperaccumulated metals and major elements (*i.e.* Ca, K, P, S) through the mineralisation of hyperaccumulator litter. Therefore, this PhD project aims to answer the following key research question:

What are the Ni fluxes and dynamics across the soil-plant compartments in a tropical 'metal crop' system on ultramafic soils?

To answer this question, it is necessary to set up a designed field system that can be manipulated in specific experiments (including: removing deposited litter, biomass harvesting, supplementation with targeted fertilisation). The model system and biological resources (metal crop species) are in Sabah (Malaysia) where a fully characterised 1.5-ha experimental plot has been set up. Native metal crop include *Rinorea bengalensis* and *Phyllanthus securinegioides* whose nutrient requirements have been characterised during the PhD Project of Philip Nkrumah (UQ, supported by LabEx Ressources21). Designing the crop systems and cropping scenarios will make use of the results obtained in a large randomised-block dosing experiment using pots (Nkrumah, 2017). The level of litter deposition and cropping mixes will be designed to properly address the key scientific question. Full control and elemental balance of the systems will be carried out. Porous cups will be installed to monitor soil solution dynamics and all data will be mapped. This PhD project will strive to answer the following questions:

1. What are the dynamics of Ni recycling from the deposited litter of hyperaccumulator plants?
2. How to model the Ni fluxes in these ecosystems?
3. Are hyperaccumulator plants the main source of available Ni in the surface of ultramafic soils?
4. What is the rate of the exhaustion of the available Ni pools in soils under agromining (outputs >100 kg Ni ha^{-1} yr^{-1})?

Research programme:

The candidate will target these questions using ecosystem manipulation of full-field scale plots of *Rinorea bengalensis* and *Phyllanthus securinegioides* that have been set up for the programme 'Ni' of R21 in Sabah (Malaysia). The experimental approaches of this project are as follows:

1. Agronomic – including optimisation of cropping conditions and crop modelling;
2. Ecosystem manipulation, which includes biomass monitoring, control of biomass fluxes, control of litter deposition, harvesting, mass balances of water and contained elemental fluxes;
3. Time-resolved monitoring of pore water composition using porous cups;

4. Nickel stable isotope tracing using ^{61}Ni to monitor the dynamics of Ni fluxes between system compartments, including those that feed to the soil available Ni pool (weathering of Ni-bearing phases, litter deposition, uptake by plants, leaching, *etc*.);
5. Geochemical modelling, together with 'metal crop' modelling, the simulation of the long-term impact of repeated hyperaccumulator crops on the Ni compartments. The models will be calibrated with the dataset collected during the first two years of field experiments.

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