Priming effect is a potential tool for agroecologyin the tropics.

Laetitia Bernard[1], Tantely Razafimbelo[1], Tiphaine Chevallier[2], Lilia Rabeharisoa[1]and Eric Blanchart[1].

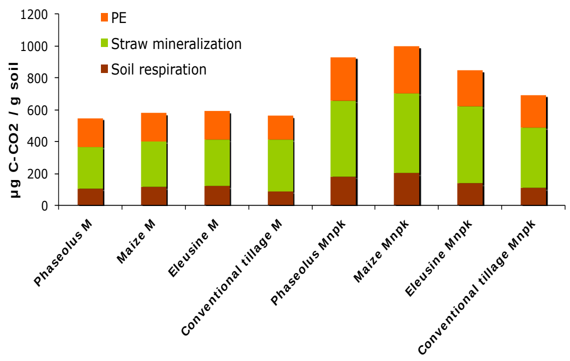
[1] Laboratoire des RadioIsotopes/IRD, BP 3383, Route d'Andraisoro, 101 Antananarivo, Madagascar. Email: laetitia.bernard@ird.fr
[2] IRD, UMR Eco&Sols, 2 Place Viala, 34060 Montpellier, France

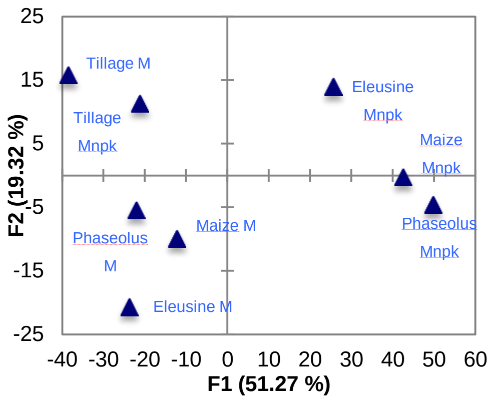
Malagasy soils as most tropical soils are agedand therefore with a highly weathered parent material(Vitousek et al., 2010, Yang and Post, 2011). As a consequence, those soils are severely depleted in total Phosphorus and more than half of it belongs to the organic matter pool, which is not available to plants. Moreover the inorganic P availability is strongly restricted because of its high affinity for clays or for metal oxyhydroxydes like Fe(III) or Al. In lowland areas covered by rice fields, flooding increases Phosphorus availability by the stimulation of microbial Fe(III) reduction especially in presence of organic amendment like rice straw (Rakotoson et al. 2014). Decomposition of organic matter induces more reductive power and liberates also organic anions outcompeting P on sorption sites (Tian et al 2008). This last process is also present in non-flooding aerobic soils. Rainfed cropping systems are in expansion in Madagascar to face the increasing food demand and because lowland are saturated. The problem of highlands (Tanety) is the poor quality of soils depleted in organic matter and nutrients. Conservation agriculture, based on its three characteristics of reduce tillage, promote crop rotation and association, and permanently cover soil with dead or alive organic mulches, constitutes an opportunity to regenerate highlands soils for food production. In such systems, organic matter management plays a key role in the restoration of fertility.

Fresh organic matter (FOM) entering the soil is decomposed by microorganisms, namely Bacteria and Fungi, and slowly converted into more chemically stable compounds with higher residence time, called chemically stabilized organic matter (CSOM) and usually associated with colloids. During this stabilization process, many carbon atoms are lost by microorganism respiration and reach the atmosphere. Consequently, CSOM is getting richer in N and P but requires more and more energy to be decomposed. Sometimes, the decomposition rate of this recalcitrant material is modified by the addition of fresh organic matter.This phenomenon called priming effect –PE- (stimulation of the CSOM mineralization rate) can also lead to the recycling of nutrients (N and P) trapped into the CSOM, which could benefit the crop growth(Kuzyakov et al., 2000).

It has been proposed that the PE results from the activity of few aerobic specialized microbial populations, which use the energy contained in FOM to break the CSOM and to access the nutrients trapped insideunder nutrient limiting conditions(Fontaine et al., 2003). If such decomposers would be outcompeted by fast-growing populations (opportunists) for labile compounds (sugars, organic and amino acids…) they could be more efficient for the most recalcitrant part of FOM (cellulose, hemicellulose, lignin, aromatic compounds). Therefore, the aerobic status of soil, the quality of fresh organic matter and the availability of nutrients should shape the composition of microbial communities and control the intensity of the PE. All those determinants being driven by agricultural practices, the control of the balance between humification and nutrient recycling routes appears possible, in function of crop needs.To reach this objective, identification of bacterial and fungal populations belonging to different functional guilds could lead to the definition of bioindicators of the balance between stabilization and mineralization routes of soil organic matter transformation.

We have investigated whether tillage, quality of mulches and mineral fertilization could shape the composition of soil microbial communities and therefore their capacity to mineralize FOM and CSOM and to generate PE. Soil from rice fields cropped under DMC (Direct-seedling mulch based cropping) or conventional systems has been sampled (SPAD agronomic trial, Andranomanelatra). For DMC systems, samples were taken right below 3 different mulches corresponding to the different rotations (maize, phaseolus and Eleusine). Only one condition corresponded to the conventional tillage system as residues of the precedent culture were systematically exported after been harvested. Those four modalities were crossed with two level of fertilization: one based on manure amendment (M) and the second corresponded to a mix of manure and NPK (MNPK). Mineral N and P were quantified on soil samples. Those samples were further incubated for one week in the presence or not of 97% ^{13}C labeled wheat-straw (4mg/g soil) to measure the capacity of each microbial community to mineralize CSOM, FOM and generate PE. After CO_2 analysis, DNA was extracted from samples, separated on the basis of its ^{13}C enrichment (DNA-SIP technique Bernard et al. 2007). Bacterial communities composition and structure of both light and heavy DNA fractions from samples were assessed by high throughput sequencing techniques in order to know who was feeding on labeled FOM or on non-labeled CSOM.



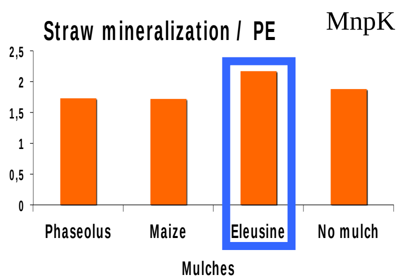


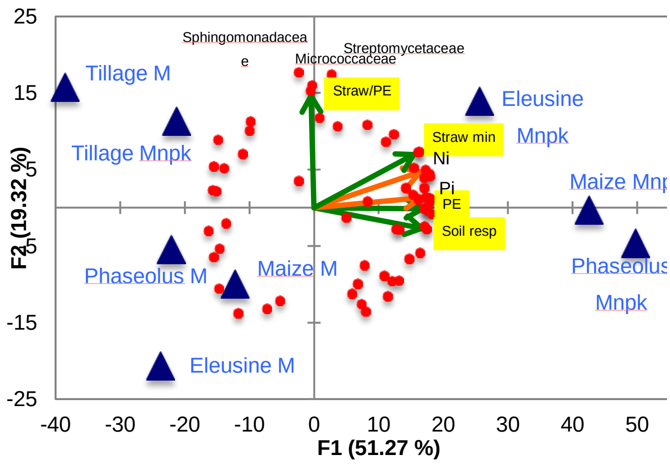
A **B**

The main field factor controlling fresh and soil organic matter mineralization is the ***fertilization type*** (Fig A). However, this effect is indirect as the conventional tillage practices, with no residue returning to soil, showed similar patterns of CO_2 mineralization as well as microbial communities structure (Fig B). Mineral fertilizers have increased the crop biomass produced, and therefore the amount of residues returned to the soil after harvest.

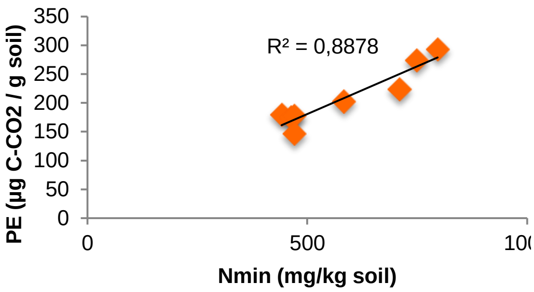
Under Mnpk fertilization, the Eleusine mulch favors the **straw mineralization *vs* PE** (Fig. C)*via* the selection of several families like **Micrococcaceae and Streptomycetaceae** (Fig. D). Those families were mostly retrieved in the heavy DNA fraction (^{13}C enriched), which confirmed that those families fed preferentially on fresh residues.

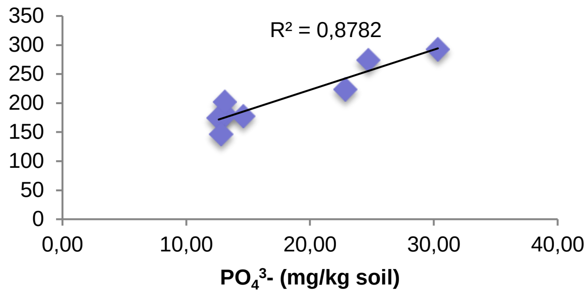
PE positively correlated to the concentration of the nutrients N and P available in the soil before incubation (Fig.E& F). The higher potential PE we measured could reflect situations of stronger real PE in the field, resulting in higher N and P recycling from the CSOM.





C **D**

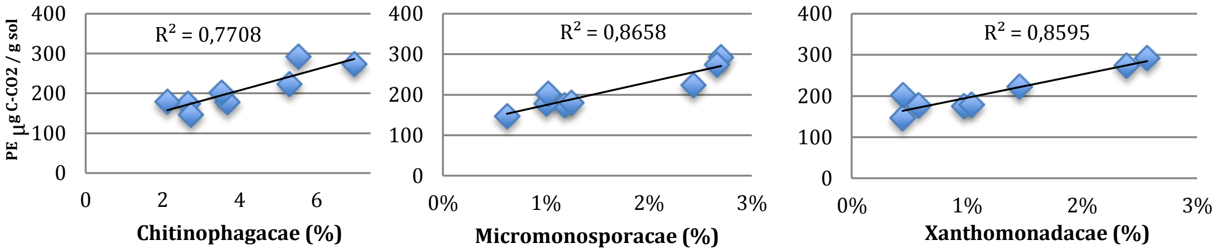




E **F**

Here is an example showing that different agricultural pratices can shape the microbial communities structure and therefore influence their mineralization profiles and the recycling of nutrients valuable for crop growth. Therefore, organic matter managment can influence the balance between stabilization and nutrient recycling routes. Another way to contrôl this equilibrium at the root scale is the use of earthworms. Earthworms are ecosystem engineers as they modulate the availability of resources to microbial species, by altering edaphic parameters, such as soil structure, pH, O_2, water regime etc. Earthworms provide labile FOM, present in their mucus, and increase decomposition by favoring the contact between microorganisms and their substrates, via the mixing effect of gut transit. As C mineralization usually increases in the gut transit and fresh casts(Lavelle and Martin, 1992), as well as nutrients enrichment, earthworms should modulate both C over-mineralization and the microbial loop mediated nutrient recycling. An example of the effect of earthworm on microbial communities structure and their C mineralization profile is developed on a poster entitled **Plant-earthworm partnership to increase crop productivity in the tropics.**

Identification of populations responsible for Priming Effect generation would help to understand the process. From the previous study and those involving earthworms, we could propose a set of families, which correlated with PE intensity (Fig. G):**Chitinophagacae, Flavobacteriacae, Xhantomonadacae, Micromonosporacae, Opitutacae, Kofleriacae**….



G

We have therefore to pay attention to those families as well as those feeding preferentially on fresh organic matter, in order to define some bioindicators of both humification and nutrient recycling routes.

A new project entitled “Global change effect on the diversity of soil microorganisms, in West Africa and Madagascar, and its consequences on ecosystem services (CAMMiSolE) and funded by the French “Fondation pour la Recherchesur la Biodiversité” has begun in may 2014. This project regroups 4 academic partners (IRD, INRA, LRI, ISRA) and 2 NGO (AgriSud international and Association Song Kooadba) and will study how climate and land use can modify microbial structures and whether such modifications induce different organic matter mineralization profiles (FOM, SOM and PE) and intensities of nutrient recycling. The project aims to build a tool based on multi-scale modelling approach, which integrates the tripartite relationship between global changes, microbial diversity and ecosystem services. This tool should allow building any biodiversity scenarios and will therefore be a decision-making tool for farmers to increase or stabilize their production at short time scale by the optimization of agricultural practices to physicochemical soil parameters and at a longer time scale by the anticipation of climatic changes.

References

Bernard L, Chapuis-Lardy L, Razafimbelo T, Razafindrakoto M, Pablo AL, Legname E, Poulain J, Brüls T, O’Donohue M, Brauman A, Chotte JL and Blanchart E. 2012. Endogeic earthworms shape bacterial functional communities and affect organic matter mineralization in a tropical soil. ISME Journal. 6: 213-222.

Bernard L., Mougel C., Nowak V., Henault C., Lévêque J., Maron P.A., Haichar F.Z., Berge O., Marol C., Balesdent J. and Ranjard L. 2007. Dynamics and identification of soil microbial populations actively assimilating carbon from 13Clabelled wheat residue as estimated by DNA- and RNA-SIP techniques. Environmental Microbiology, 9 : 752-764.

Fontaine S, Mariotti A and Abbadie L. 2003. The priming effect of organic matter: a question of microbial competition. Soil Biology and Biochemistry. 35:837-843.

KuzyakovY, Friedel JK, and Stahr K. 2000. Review of mechanisms and quantification of priming effects. Soil Biology and Biochemistry. 32: 1485-1498.

Lavelle, P., Martin, A., 1992. Small-scale and large-scaleeffects of endogeicearthworms on soilorganicmatterdynamics in soils of the humidtropics. SoilBiology&Biochemistry 24, 1491–

1498.

Rakotoson T, Amery F, Rabeharisoa L and Smolders E. 2014. Soil flooding and rice straw addition can increase isotopic exchangeable phophorus in P-deficient tropical soils. Soil Use and Management. 30: 189-197.

Tian J, Liu L, Ding HS and Chen T. 2008. Mobilization and transformation of phosphorus from water-soil interface of flooded soil. Huan Jing KeXue. 29 : 1818-1823.

Vitousek PM, Porder S, Houlton BZ and Chadwick OA. 2010. Terrestrial phosphorus limitation : mechanisms, implications, and nitrogen-phophorus interactions. Ecological Applications. 20(1) : 5-15.

Yang X and Post WM. 2011. Phosphorus transformations as a function of pedogenesis: A synthesis of soil phosphorus data using Hedley fractionation method. Biogeosciences. 8:2907-2916.