Ecological intensification of soil processes for agrosystem services in the tropics

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INTRODUCTION

The transition from intensive agriculture to more environmentally friendly agroecological practices that better reflect the expectations of sustainability and development has been widely documented.

With the development of agroecology, soil plays a particularly important role in the design of innovative sustainable agricultural practices.

Many studies stress the need to **promote soil biodiversity in cultivated systems** (Brussaard, 2010). Consequently, characterizing, understanding and optimizing soil ecological functions within agrosystems appears an urgent necessity (Fig.1).

Here we propose a methodology of soil ecological intensification based on ecological theories with the aim to deliver agrosystem services. A result from an ongoing project in Madagascar, on upland rainfed rice, is given to validate this approach.

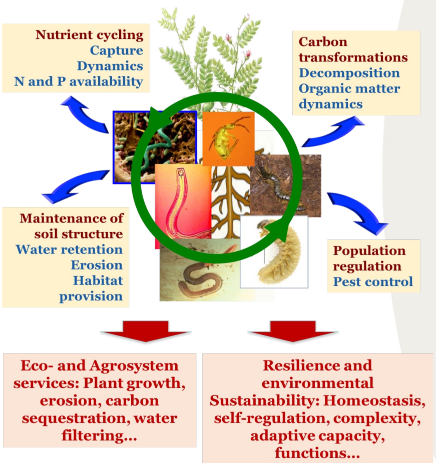

Fig.1. Relationships between soil biodiversity – processes, functions and ecosystem services (from Kibblewhite et al., 2008)

References

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METHODOLOGY

We propose a 4-step procedure for intensifying ecological soil processes with the aim to increase both agrosystem productivity and sustainability (Fig.2)

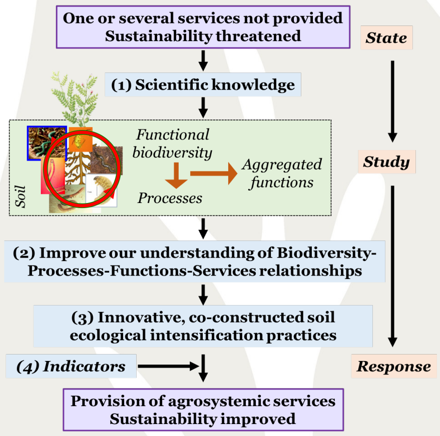

Fig.2. Methodological approach

(1) **a local diagnosis of dysfunctions**. This requires local action both in the diagnosis and understanding of soil ecological processes and in the deployment of appropriate tools.
(2) **a detailed and integrative understanding of soil ecological processes** involved in ecosystem functions and related to the diagnosed dysfunction(s).
(3) **a co-construction of agricultural practices,** with stakeholders, allowing Ecological Intensification of Soil Processes.
(4) finally, **indicators of ecological soil intensification are deployed** to measure the effect of practices on long-term ecological processes of the soil.

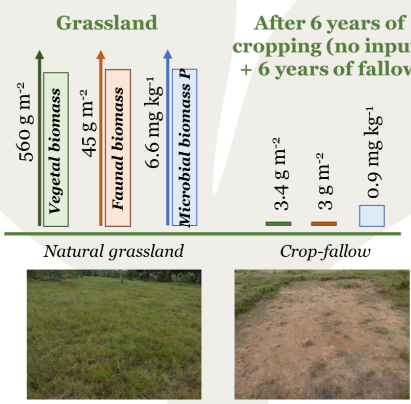

Fig.3. Low resilience and high vulnerability of Ferralsols in Madagascar: inefficient soil management results in 'highly degraded soils'

MAIN RESULTS

(1) The Ferralsols from the Highlands of Madagascar have a very poor fertility resulting in a low productivity of both natural grasslands and crops. A poor management of crops, i.e. without fertilization, commonly results in 'highly degraded soils' characterized by a low vegetation recovery and very low macrofauna and microbe biomass (Fig. 3).
Such a low development of soil organisms and vegetation is linked to important deficiencies in C and different nutrients, especially P, Mg, N, Ca, S (Raminoarison et al., 2019).

(2) In this kind of soils, it is particularly important to increase soil biota, which can increase plant growth, plant nutrition, plant tolerance to pathogens. For instance, endogeic earthworms (*Pontoscolex corethrurus*) have been shown to increase rice growth and nutrition, especially by increasing P fluxes to rice (Fig. 4), and to increase resistance of rice to blast disease (Blanchart et al., 2020)

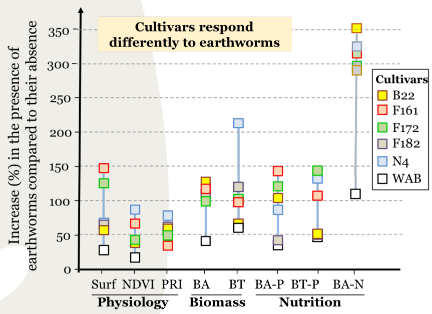

Fig.4. Percent increase of various key plant traits due to earthworm presence according to rainfed rice cultivars (Surf=Specific leaf area, NDVI= Normalized Difference Vegetation Index, PRI= Photochemical Reflectance Index, BA= aerial biomass, BT= total biomass, BA-P= amount of P in shoot, BA-N= amount of N in shoot) (in prep.)

(3) The multi-nutritional limitation of the soil biota requires an integrated soil fertility management based on organic inputs because NPK fertilizers are neither efficient to sustain biological activity nor plant growth; moreover mineral fertilizers can increase pathogen development. A 3-year field experiment compared a large panel of fertilization practices including organic and organo-mineral ones.

(4) A global indicator of soil ecological functioning, based on 73 soil measures and a global indicator of plant growth, based on 19 measures allowed scientists and farmers to evaluate the efficiency of these practices (see poster by Bernard et al., this symposium) and to develop innovative practices where biological activities prevail.