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CANSEA a R&D Network on Agroecology Transition in South East Asia

Functional IndicatoR of Soil ecosysTem (FIRST): investing in SMART tools to assess soil biological functioning

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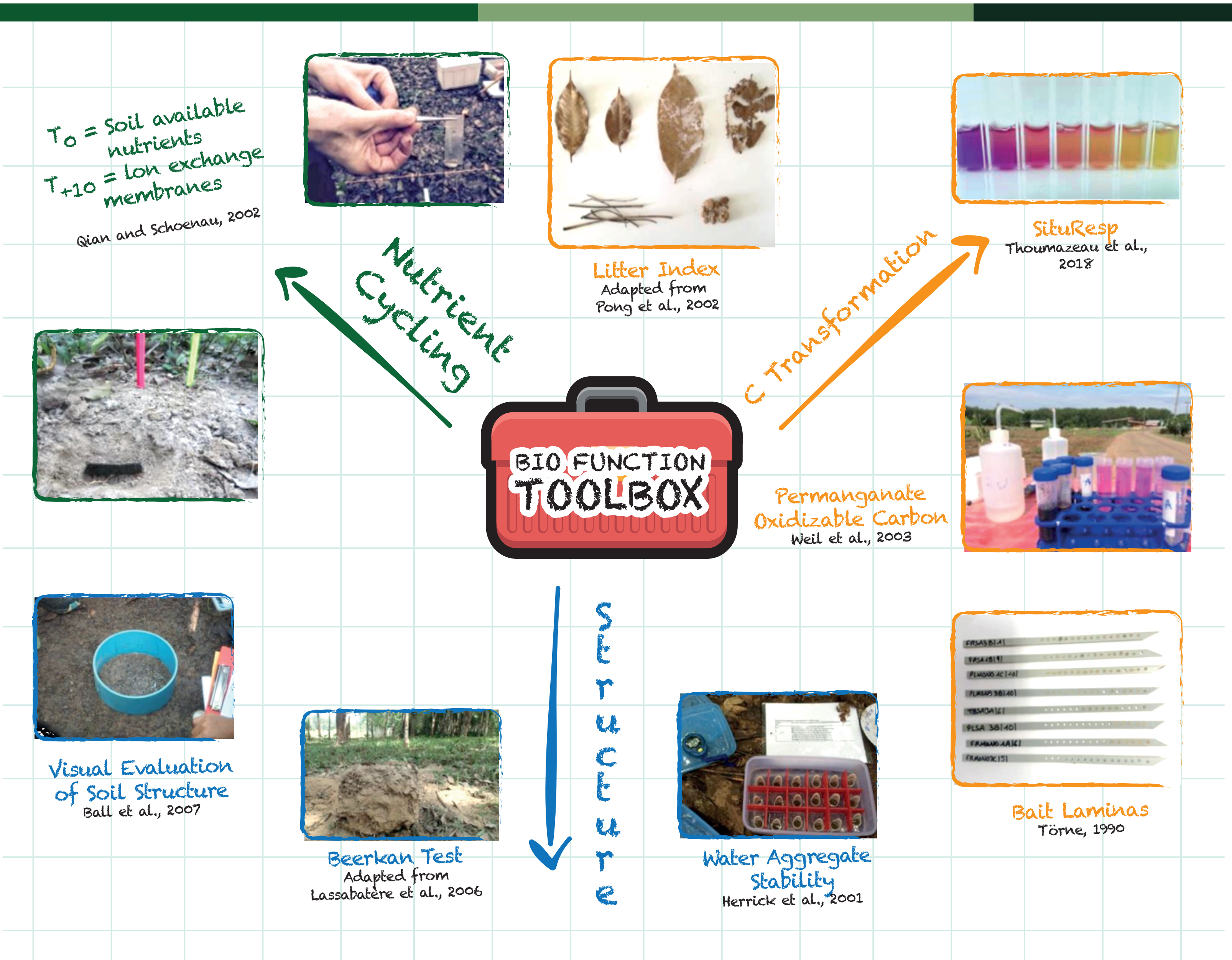


Key results and lessons learned from the Action

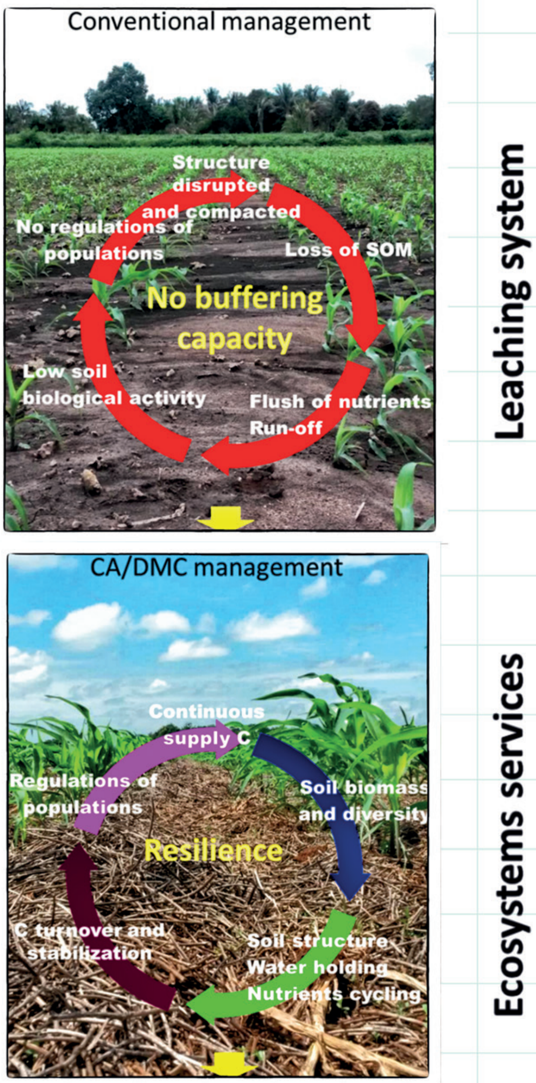
There is a need to better account for soil functioning in the evaluation of soil quality. Soil functioning is the result of soil physico-chemical and biological interactions. A set of ten biological functional tools (Biofunctool®) was developed and used to assess the impact of different land use and cropping systems on soil functioning in Laos and Cambodia.

First results show that the three major soil ecosystem functions (i.e. carbon transformation, nutrient cycling, and soil structure maintenance) are affected by soil disturbance (e.g. significant decrease of soil quality index - SQI - under tillage-based systems as compared to no-till systems) and total biomasses restituted to the soil (e.g. SQI mono-cropping < SQI inter-cropping systems). The quantity and quality of biomass inputs appear as a key driver of soil quality maintenance up to improvement under conservation agriculture-based cropping systems. Similar results were observed in other sites (e.g. New Caledonia) where Biofunctool® was tested on cropping systems transitioning from plough-based to no-till and mulch-based management, emphasizing the robustness of the tool and its effectiveness to quantify early changes in soil quality.

In addition, Biofunctool® is a good, easy-to-apply, and cost-efficient pedagogical tool that allows sensitizing and building capacities on land use impact assessment. FIRST has contributed to the capacity building of a large range of partners (researchers, technicians, Bsc and Msc students) in Laos and Cambodia. Two main trainings were organized in Thailand by the Land Development Department, Khon Khaen University, UMR Eco&Sols and LMI LUSES bringing together 29 participants from 4 countries (Cambodia, Laos, Thailand, France). Two additional trainings were organized in Laos and Cambodia bringing together 20 and 12 participants respectively in October and November 2017. In Cambodia, the Faculty of Agronomy Science of the Royal University of Agriculture has the lead today regarding the implementation of the Biofunctool at the national level and has the ability to answer to request from development operators, research teams, among others. Four Msc students (3 in Cambodia and 1 in Laos) used the Biofunctool has a core element of their studies assessing the impacts of land use changes (from forest to cultivated land) and contrasted soil and crop management on soil quality.

However, improvements are still needed to better adapt the tools to annual cropping systems, sloping land, and the current limited lab facilities in Laos and Cambodia (e.g. impossibility to locally analyze membranes and soils solutions).

The Permanganate OXidizable Carbon (Pox C) to Soil respiration (SituResp) ratio appears to be an excellent proxy of land use management impact on soil organic carbon (hence soil quality) dynamics, and should be promoted at *minima* in land use impact assessment studies.



Soil biological functioning under till vs CA-based cropping systems (adapted from Sà, 2003)

Context of the Action

Soil quality, which can be simply defined as "the capacity of the soil to function" (Karlen et al., 2003), is globally threatened by many risks such as erosion, contamination, organic matter depletion, compaction, or salinization. The current rate of soil degradation threatens the capacity to meet the needs for future generation.

In this perspective, there is a need to develop simple (low-tech) but effective tools to assess land use impact on soil quality. Considerable efforts have been made to develop evaluation tools to characterize the productivity and the sustainability of different management systems. Most of them are based on the measurements of soil physico-chemical parameters (i.e., pH, nitrate, water holding capacity etc.).

However, these approaches do not take into consideration the complex biotic interactions that makes the soil to function. Soil quality is dependent on the maintenance of three major ecosystem functions: 1/ carbon transformation, 2/ nutrient cycling, 3/ soil structure maintenance. Each of these three functions is related to a specific functional assemblage of soil organisms under the influence of abiotic factors.

Objectives of the Action

The objective was to better take into account the functional role of soil biota in the evaluation of soil quality. A set of ten biological functional tools (biofunctools) was developed and used to assess the impact of different land uses and cropping systems on soil quality.

Soil function	Tool	Description
Carbon transformation	Permanganate OXidizable Carbon (POXC)	Estimation of the labile fraction of SOC (mg.kg-1soil)
	Basal Soil respiration (SituResp®)	Assessment of soil biological activity through CO2 release from a fresh soil sample. Difference of absorbance between T0 and T+24h.
	Lamina baits	Assessment of soil biological activity through the decomposition of a substrate in contact with the soil. Score from 0 (no degradation) to 1 (complete degradation)
	Litter index and cast density	morpho-functional diagnosis describing the state of litter degradation on soil surface (fragment and skeleton in % of total leaves)+ quantification of earthworm casts density (g.m-2)
Nutrient cycling	Ion exchange membranes	Assessment of the dynamic of soil available nutrients using an exchangeable membrane that easily adsorb nutrients in a solution (mgN.kg-1 soil)
	Soil available nitrogen	Measurement of soil available nitrogen per mass of soil (µgN-NO3-.cm-2.d-1)
Soil structure maintenance	Aggregate stability (AggSurf and AggSoil)	Assessment of soil structure behavior under the effect of water, wind and management practices at two depths (0-2 cm and 2-10cm). Score from 1 (poor aggr. stability) to 6 (high aggr. stability)
	Beerkan	In situ assessment of water infiltration rate in soils (ml.min-1)
	Visual Evaluation of Soil Structure (VESS)	Assessment of soil structure linked to the biological assemblages in the field, classifying the soil structure of each layer into five scoring classes: from 1 (very friable soil) to 5 (very compacted soil)

Partnership

Cambodia: General Directorate of Agriculture (GDA) under the Ministry of Agriculture, Forestry and Fisheries (MAFF), Conservation Agriculture Service Centre (CASC) under the Department of Agricultural Land Resources Management (DALRM), Royal University of Agriculture (RUA), Institute of Technology of Cambodia (ITC), and CIRAD

Thailand: Khon Khaen University (KKU), Land Development Department (LDD), and Institut de Recherche pour le Développement (IRD)

Laos: Department of Agricultural Land Resources Management (DALAM) under the Ministry of Agriculture and Forestry (MAF), and CIRAD

France: Montpellier Supagro

The action was supported by the French Development Agency (AFD) and the Cambodia Climate Change Alliance (UNCCD-CCCA), Ecological Intensification and Soil Ecosystem Functioning (EISO-FUN), Window for Research and Innovation Projects.

Location and description of the Action

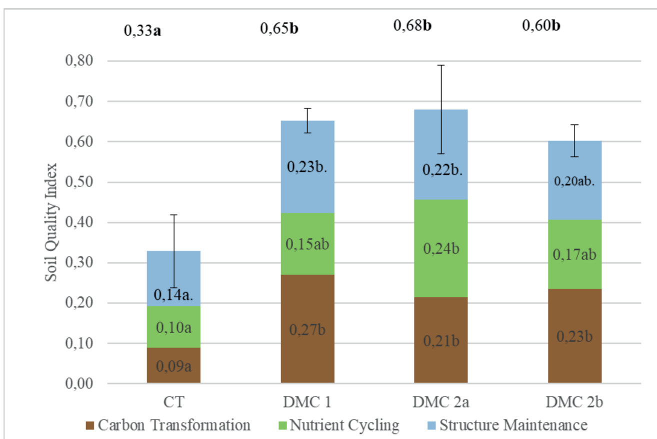
Biofunctool was tested in three contrasted agroecosystems:

- In Cambodia, Kampong Cham Province: Bos Khnor research station (red oxisols, 68% clay); assessment of 3 no-till and mulch-based (DMC) vs 1 conventional (tillage-based) cropping systems (soybean-based experiments conducted since 2009)
- In northern Laos, Xieng Khouang Province: maize-prone production area, permanent agriculture on moderate slope and clay-loamy soils (35-40% clay); assessment of four different land uses (LUs): maize mono-cropping, maize intercropped with rice bean, improved pasture of ruzi grass, and forest
- In northern Laos, Luang Prabang Province: upland rice-based area, shifting cultivation; assessment of four different LUs on steep slopes and clayey soils (55-60% clay): upland rice, upland rice intercropped with pigeon pea, improved pasture of ruzi grass, and forest

Biofunctool® training in Xieng Khouang Province, Laos; on-farm testing of soil aggregate stability (credit photo @ Lienhard 2017)

Capacity of Biofunctool® to discriminate land use and agricultural practises impact on soil quality

Good discrimination capacity at site level (e.g. DMCs vs CT; annual vs perennial land use systems); good sensitivity to early changes (e.g. recent integration of legume crop in rice/maize mono-cropping systems).



Biofunctool® soil quality index calculated for till vs no-till cropping systems in Cambodia, Bos Khnor station

Assessment of the tool set using SMART analysis grid

Specific – **M**easurable – **A**chievable - **R**elevant – **T**ime bound

Tool		SMART assessment
Permanganate OXidizable Carbon (Pox C)	S	Specific to labile carbon
	M	Quantified measure of labile C which is strongly correlated to soil C input
	A	Low unit cost/sample; some initial investments needed (portable spectrophotometer ~600 US; some lab equipment e.g. pipette needed for dilutions); smartphone reading tool under validation
	R	Highly relevant
	T	Instant measurement
Basal Soil respiration (SituResp®)	S	Specific to soil microbial respiration
	M	Direct and quantified measure of soil basal respiration
	A	Low unit cost/sample; some initial investments needed (portable spectrophotometer); some lab products possibly difficult to find (Cresol Red, soda lime); smartphone reading tool under validation
	R	Highly relevant
	T	24H needed
Lamina baits	S	Specific to soil mesofauna activity
	M	Direct measure of activity; scoring method; indirect measure of soil C degradation
	A	Variable costs (locally-made baits and substrate vs purchased); relatively expensive if C substrate purchased; possible damages by fauna
	R	Relevant
	T	Time-consuming (baits preparation and installation; 7 to 10 days needed; reading and computing)
Litter index and cast density	S	Specific to macrofauna and mesofauna activity
	M	Quantified measure of litter degradation status
	A	Limited material needed; low-cost (if labor not included in cost calculation)
	R	Globally relevant; little relevant for till-based systems (litter annually buried in soils)
	T	Time-consuming (sampling and drying operations; data computing)
Ion exchange membranes	S	Specific to nutrients dynamics in soils
	M	Quantified measure of soil available nutrients
	A	Membranes (anion & cations) to be purchased in foreign countries; membranes re-use opportunity to be tested; limited lab with capacities to analyze membranes solutions; possible damages by fauna
	R	Globally relevant; difficult to implement on slopes
	T	Time-consuming (membranes preparation and installation; 7 to 10 days needed; solution extraction)
Soil available nitrogen	S	Specific to soil available N
	M	Direct and quantified measure of soil available N
	A	Cost of lab analysis (+ lab analysis capacity)
	R	Relevant notably in cereal-prone production area (rice, maize)
	T	Dependent of lab facilities
Aggregate stability (AggSurf and AggSoil)	S	Specific to soil aggregate stability
	M	Direct measure; scoring method
	A	Low unit cost/sample; some initial investments needed (sieves)
	R	highly relevant but site specific. For cross-sites analysis, co-variables such as soil texture are needed
	T	10 minutes/ 18 samples
Beerkan	S	Specific to soil water infiltration capacity
	M	Direct and quantified measure of water infiltration
	A	Low-cost and limited material requirements
	R	Globally relevant; soil texture as supplementary data would improve the quality of indicator; not relevant on slopes
	T	5-40 minutes/sample
Visual Evaluation of Soil Structure (VESS)	S	Not specific; assessment of global soil structure quality
	M	Qualitative assessment; scoring method
	A	Low-cost and limited material requirements
	R	Moderately relevant; observer-dependent data
	T	5-10 minutes/sample

Useful links and contacts

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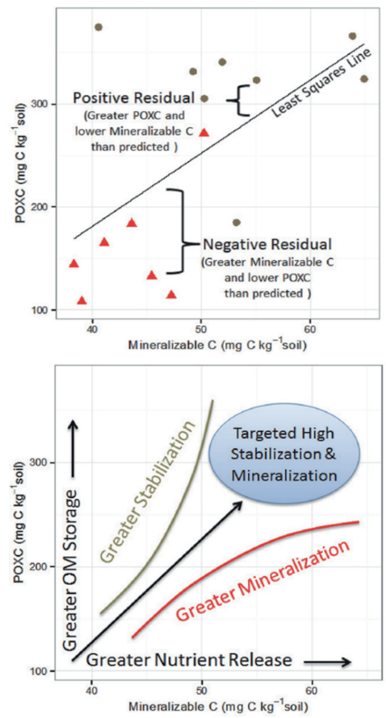
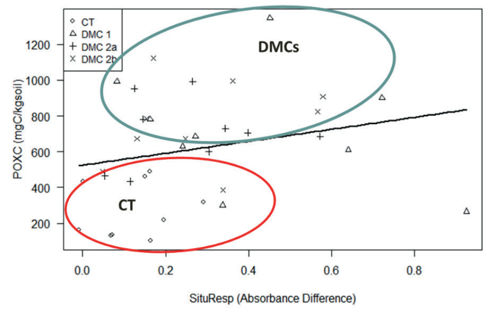
Focus on PoxC to SituResp ratio to assess land use management impact on SOC dynamics

According to Hurisso et al. (2016), labile carbon (as assessed e.g. through Pox C) to mineralizable C (as assessed through soil respiration) ratio allows to assess OC dynamics in soils (C stabilization vs C mineralization). This ratio appears as a good proxy of land use management early impact on soil quality and can be used as a simple-but-relevant decision-making tool to adapt agricultural practises (e.g. excessive animal stocking rate negatively impacting soil carbon dynamics under managed pasture and jeopardising the sustainability of the investment).



Pox C to mineralizable C ratio used to assess OC dynamics in soils (Hurisso et al. 2016)



Pox C to SituResp ratio according to cropping systems (Cambodia, Bos Khnor station)

Expected impacts and prospects

Biofunctool® allows discriminating land use management and agricultural practices based on their early impacts on soil biological functioning. Biofunctool® could therefore be used to support decision-making by providing science-based evidences of land use early impacts on soil quality.

In addition, Biofunctool® is a good, easy-to-apply, and cost-efficient pedagogical tool that allows sensitizing and building capacities on land use impact assessment.

However, improvements are still needed to better adapt the tools to annual cropping systems, sloping land, and the current limited lab facilities in Laos and Cambodia. The aggregation of existing Biofunctool® data with local-specific supplementary data (e.g. plots history, soil texture, pH, soil humidity and temperature at sampling etc.) could be used to calibrate a predictive model allowing better cross-sites analysis.

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