Short-term effect of no-tillage on profitability, soil fertility and microbiota: a case study in a tropical ecosystem (altitude plains, Lao PDR)

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Introduction

The Plain of Jars is a vast, acid and infertile savannah grassland located in the western part of Xieng Khouang Province, north-eastern Lao PDR. The farming systems in this region are mainly based on lowland rice cultivation and extensive livestock production. With limited opportunities for agricultural expansion in the lowlands, the development of agricultural production in the uplands is a key challenge for the subsistence farmers. Since the last decade, many attempts, all based on soil tillage for land preparation, have been made to develop staple and cash crops production in the uplands. Since 2007, conservation agriculture (CA) systems, largely presented as more sustainable systems than conventional ones (Hobbs et al, 2008), have also been tested. However, there is limited information regarding the profitability of these practises and their environmental footprints in such agroecology. In order to evaluate the short term agri-environmental impact of various land use management, agronomical and economical performances of four different till and no-till systems were monitored during the first years of trials implementation (2007-2010 period). The impact of these practises on top soil (0-10cm) chemical characteristics, aggregate stability and microbial communities' evolution was evaluated in 2009 by comparison with the natural surrounding pastureland (PAS).

Material and Methods

A 3-years rice / corn / soybean rotation was conducted both under conventional (CV) and direct seeding mulch-based cropping (DMC) systems (compared land use description in table 1). Yields, production costs and labour required were yearly recorded for each elementary plot. Aboveground biomasses were yearly measured for each plot on 10 squares of 4m2 each. Belowground biomasses were estimated from above ground biomasses using crops indexes. Chemical characteristics were analysed in France at CIRAD's Soil Analysis Laboratory using international standards. Soil aggregate stability was estimated through various aggregate indices based on aggregate size distribution after wet sieving (Yoder method, calculation of the Mean Weight and Mean Geometric Diameter -MWD and MGD- of aggregates) and soil texture (Aggregate Stability Index -AS- developed by Castro Filho and al, 2002). Microbial abundance and diversity was evaluated using molecular tools as described by Ranjard et al (2001): After extraction and purification of soil microbial DNA, bacterial and fungal populations were quantified using quantitative Polymerase Chain Reaction (qPCR 16 and 18S); bacterial communities' diversity was analysed through B-ARISA (bacterial automated ribosomal intergenic spacer analysis) fingerprints analysis.

Results and Discussion

No significant differences were observed regarding agricultural systems profitability with equal cumulated production costs, labour and yields for the four first years of implementation (see table 2). However significant differences were observed regarding total aboveground and belowground biomasses produced and brought back to the soil with higher dry matter restitutions for all three DMC systems compared to CV system (see table 2). These differences associated with differences in land preparation (no-till vs tillage) might explain the significant differences observed between CV and all three DMC systems regarding soil chemical and physical characteristics evolution. Lower values of pH, organic C, total N and CEC were observed for CV system (see table 3) as well as a decrease in soil structure stability with lower macro aggregates (0.25–19mm) and lower aggregation indexes values (see table 4). Regarding indigenous microbiota evolution, slight modifications were observed with the distinction of three indigenous bacterial communities under CV, DMCs and PAS shown by B-ARISA fingerprints analysis (see figure 1). These first observations confirmed the early impact of ploughing on top soil degradation process and the interactions between Soil Organic Matter, soil biota and soil structure as described by Six et al (2002). Macro aggregates disruption, enhanced soil aeration and mixing of residues into the soil induced changes in microbial communities' activity and organic C losses. These results observed after only two years of cultivation also confirmed how fast soil degradation can occur in the tropics.

References

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Figures and Tables

Land Use	Rep	Description
PAS	16	Savannah grassland dominated by *Themeda triandra* and *Cymbopogon nardus* species
CV	25	Land preparation based on ploughing using discs and burying of crop residues
DMC		No-tillage; direct seeding after mechanical and chemical control of cover crops
DMC 1	25	Year 1: "*fing+pig*", then 3y rotation rice+*sty* / corn+*fing+pig* / soy bean +*oat+buck*
DMC 2	25	Year 1: "*fing+sty*", then 3y rotation rice+*sty* / corn+*sty* / soy bean +*oat* +*buck*
DMC 3	25	Year 1 "*ruzi+pig*", then 3-year rotation rice+*sty* / corn+*ruzi* / soy bean +*oat* +*buck*

Fing = finger millet (*Eleusine coracana* Gaern), *pig* = pigeon pea (*cajanus cajan* cv Thai), *sty* = stylo (*stylosanthes guianensis* cv CIAT 184*), oat* = oat (*Avena sativa* L.), *buck* = buckwheat (*Fagopyrum esculentum* Moench), *ruzi* = ruzi grass (*Brachiaria ruziziensis* cv ruzi)

Table 1. Land use description and number of samples replicates

Syst	cum*. prod costs[1] (USD/ha)			cum. labour (md/ha)			cum. grain yields[2] (ton/ha)			cum. aboveground biomass (ton of DM/ha)			cum. roots biomass[3] (ton of DM/ha)			cum. total biomass produced (Ton of DM/ha)		
CV	1991	±272	[a]	251	±30	[b]	7,4	±3,0	[a]	12,1	±2,8	[a]	1,9	±0,3	[a]	14,03	±3,2	[a]
DMC 1	2060	±308	[a]	231	±21	[b]	8,2	±2,7	[a]	19,4	±3,9	[b]	3,8	±0,7	[b]	23,20	±4,6	[b]
DMC 2	2122	±308	[a]	238	±35	[b]	7,8	±2,3	[a]	19,2	±3,6	[b]	3,8	±0,7	[b]	23,00	±4,3	[b]
DMC 3	2111	± 305	[a]	198	± 28	[a]	6,1	± 2,8	[a]	22,3	± 4,2	[b]	6,3	± 1,3	[c]	28,63	±5,4	[c]

* cum. = average cumulated value for all 3 main crops (rice, corn, soybean) and 3 fertilization level
Letters between brackets indicate significant differences according Kruskal-Wallis test (p<0,05), Bonferroni correction
[1] production costs are calculated using average inputs prices of 2007-2010 period. [2] for 2008-2010 period; 2007 cover crops grain production are not included. [3] estimated from aboveground biomass production using coefficients of 0.18, 0.14, 0.10, 0.40, 0.27, 0.10 and 0.07 for rice, corn, soybean, ruzi grass, finger millet, stylo and pigeon pea respectively (adapted from Sà et al, 2001).

Table 2. Effect of agricultural practises on soil productivity and profitability

Syst	pH water			Corg (%)			N tot (‰)			P Olsen (mg/kg)			CEC (me/100g)			TS[1] (%)		
PAS	5,29	±0,25	[ab]	3,38	±0,46	[ab]	2,53	±0,37	[b]	3,36	±1,01	[a]	2,13	±0,81	[a]	35	±7	[a]
CV	5,19	±0,42	[a]	3,15	±0,21	[a]	2,13	±0,24	[a]	8,23	±2,50	[b]	3,32	±0,51	[a]	86	±9	[b]
DMC 1	5,54	±0,24	[b]	3,36	±0,54	[ab]	2,38	±0,30	[b]	10,61	±3,90	[b]	4,76	±1,61	[b]	95	±4	[c]
DMC 2	5,44	±0,24	[ab]	3,44	±0,46	[b]	2,40	±0,33	[ab]	10,15	±3,44	[b]	4,44	±1,35	[b]	98	±6	[c]
DMC 3	5,50	±0,25	[b]	3,44	±0,53	[b]	2,42	±0,36	[b]	9,74	±2,50	[b]	4,67	±1,64	[b]	96	±6	[c]

[1] TS = Saturation rate= (Ca+Mg+K+Na)×100 / CEC
Letters between brackets indicate significant differences according Kruskal-Wallis test (p<0,05), Bonferroni correction

Table 3. Effect of land use management on top soil (0-10cm layer) chemical parameters

Syst	Microaggregate (0-0.250 mm) (g. kg-1 soil)			Macroaggregate (0.250-19 mm) (g. kg-1 soil)			MWD (mm)			MGD (mm)			AS (%)		
PAS	47	±44	[ab]	953	±44	[bc]	8,36	±0,58	[a]	2,03	±0,17	[ab]	91	±9	[b]
CV	93	±38	[c]	907	±38	[a]	6,95	±1,24	[a]	1,67	±0,22	[a]	81	±13	[a]
DMC 1	48	±34	[b]	952	±34	[b]	9,43	±1,16	[b]	2,18	±0,28	[bc]	87	±13	[b]
DMC 2	45	±26	[ab]	955	±26	[bc]	9,46	±1,33	[b]	2,20	±0,28	[bc]	89	±14	[b]
DMC 3	33	±19	[a]	967	±19	[c]	9,70	±1,04	[b]	2,27	±0,22	[c]	92	±7	[b]

MWD = Mean Weight Diameter; MGD = Mean Geometric Diameter; AS = Aggregate Stability Index
Letters between brackets indicate significant differences according Kruskal-Wallis test (p<0,05), Bonferroni correction

Table 4. Effect of land use management on top soil (0-10cm layer) wet aggregate distribution and stability

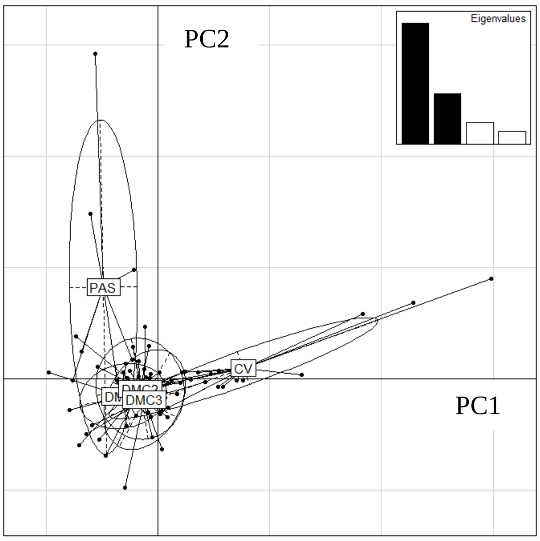

Figure 1. Effect of land use management on top soil (0-10cm layer) bacterial communities diversity (PCA of B-ARISA fingerprints, interclass, between group analysis)