Soil Organic Carbon and Soil Respiration in Conservation Agriculture With Vegetables in Siem Reap, Cambodia

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Introduction

Conservation agriculture's (CA) resource saving concept aims to achieve a balance between food production and environmental protection through implementing simultaneously three conservation practices; no-till, continuous soil cover, and diverse species rotations [1234].

However, contrasting findings in agronomic crops success under CA makes it apparent that the impacts of CA on crop yield are not certain [456&7]. Such uncertainty lies in regional differences in climate, soil, farming system, farmer knowledge, and availability of resources which can all affect crop performance under CA [6&8].

While existing literature focused on impacts of CA on agronomic crop yields, effects on vegetable yield have not been sufficiently studied especially on non-mechanized smallholder farmers. Responses of vegetable yield under CA may also be uncertain if CA is implemented without prior testing of its applicability in specific regions of the world. Also, its effect on soils may also differ due to differences in management between horticultural and agronomic crops (e.g. irrigation, weeding activity and crop rotations).

CA's and conventional tillage's (CT) effect on vegetable yield and short term soil quality were tested on commercial smallholder farms in Siem Reap, Cambodia on a soil with inherently low soil organic carbon, high hydraulic conductivity and low nutrient supplying capacity. This poster presents the short-term effects of CA and T on the soil after 2 cropping seasons.

Objectives

Determine short term effects of CA and CT on non-mechanized smallholder vegetable production on the following parameters:

- soil organic carbon
- soil total nitrogen
- soil respiration
- soil moisture
- soil temperature

Methodology

Figure 1. Cabbages with *Crotalaria juncea* covercrop planted in between rows in CA (a) and CA and CT plots after cabbages were harvested (b). Siem Reap, Cambodia.

- SOC and TN were sampled from 3 villages with 3 replications each village comparing CA and CT after 2 cropping seasons and analyzed using flash combustion method at high temperature using vario MAX CNS Elemental Analyzer at Coastal Plains Soil, Water and Plant Research Center, Agricultural Research Service, USDA, Florence, SC. SOC and TN were calculated based on bulk density of the soil.
- Field gathered soil parameters were gathered from 6 farms (2 farms per village).
- Soil Moisture were gathered in 6 locations comparing CA and CT using a Time Domain Reflectometer and field soil thermometer (TDR 100-Spectrum Tech).
- Soil Respiration, temperature were measured in 6 locations also comparing CA and CT and % waterfilled pore space were measured and calculated using soil bulk density & soil moisture[9&10].

For SOC and TN – Experimental design: randomized complete block design with 3 replications. For Field gathered soil quality measurements – Experimental design: randomized complete block design with 6 replications. Means were separated using Fisher's protected LSD test at α=0.10 SAS 9.4.

There was no fallow-period in these smallholder farms so *Crotolaria juncea* (CJ) were planted in-between rows of vegetables prior to harvesting the main crop at a rate of 30 Mg ha^{-1}. CJ were then terminated prior to planting the next crop with only having 3-4 weeks of growing time. Rice straws were used to cover CA soil at about 15 Mg ha^{-1} field dry rice straws (*Oryza sativa* L.) while CT were left bare as conventionally done.

Results & Discussion

- Sratkat Village and Trabek Village have 2.2 Mg SOC ha^{-1} and 3.1 Mg SOC ha^{-1} (averaged over 2 depths 0-10 cm and 10-20 cm) more SOC than CT, respectively (Table 1).
  - Successful growing of *Crotolaria juncea* (CJ) cover crop in both villages may have increased the SOC - Average fresh biomass production of CJ was 7.5 Mg ha^{-1} and 10 Mg ha^{-1}planted in between rows of long bean (Sratkat) and cabbages (Trabek Village)
  - Roots of main crops left on the ground plus that of CJ may also have contributed to the SOC in CA in both villages
  - Addition of field dry rice straws of about 15 Mg ha^{-1} in two (2) separate occasions before planting may have added SOC to the soil, as well, but not as much as the roots and biomass from crops (e.g. O'Village case below).
  - Yield of vegetables in CA and CT were not significantly different during the 2 growing seasons (Data not shown).
- O'Village – no observed difference in SOC.
  - Failure of growing the 2nd main crop on CA and CT may have resulted to having no observed difference. Tomatoes under CA and CT have low survival rate due to water stress from rain (rainy season) and water logging in the area during the water level rise of the Tonle Sap lake.
  - Cover crops during this time planted at the start of the dry season were abandoned (not-irrigated) due to the absence of the main crop, hence did not grow well.
  - Yield of 1st crop as well as the survival rate of the 2nd crop of CA and CT were not significantly different (Data not shown).
- Soil depth – no effect
  - SOC, regardless of treatment, were not significantly different between 0-10 cm and 10-20 cm in all Villages.
- No-interaction between soil depth and management
  - SOC, regardless of treatment, were not significantly different between 0-10 cm and 10-20 cm in all villages.

Table 1. Comparison of Soil Organic Carbon in Conservation Agriculture and Conventional Tillage in Research Sites, Siem Reap, Cambodia

Production Management	-------O' village-----			--------Sratkat Village--------			-------Trabek Village----		
	---------Depth---------			---------Depth---------			---------Depth---------		
	0-10 cm	10-20 cm	Mean	0-10 cm	10-20 cm	Mean	0-10 cm	10-20 cm	Mean
	-----------------Soil Organic Carbon (Mg ha^{-1}) -----------------								
CA	10.5±1.3	13.6±3.4	12.1±2.9	13.3±5.3	11.9±3.2	12.6±4.0^a	14.2±2.7	12.5±3.0	13.3±2.7^a
T	14.3±6.1	12.6±4.9	13.4±5.1	10.2±2.1	10.5±2.3	10.4±2.0^b	11.4±2.1	9.0±1.2	10.2±2.0^b
Mean	12.4±4.4	13.1±3.8		11.7±4.0	11.2±2.6		12.8±2.6	10.7±2.8	
SV	F-value	*p*		F-value	*p*	$LSD_{0.10}$	F-value	*p*	$LSD_{0.10}$
Block	8.74	<0.01***		10.63	0.01**		2.61	0.15^{ns}	
Management (M)	0.88	0.38^{ns}		4.12	0.08*	2.1	7.11	0.04**	2.2
Depth (D)	0.27	0.62^{ns}		0.25	0.63^{ns}		3.14	0.13^{ns}	
M*D	2.61	0.16^{ns}		0.54	0.49^{ns}		0.11	0.76^{ns}	

$^{***}p \leq 0.01$; $^{**}p \leq 0.05$; $^{*}p \leq 0.10$; ^{ns}Not significant; CA=Conservation agriculture; T=Conventional tillage; SV Sources of Variation
Means under each column with different letters are significantly different

- Sratkat Village and Trabek Village have numerically higher Total Nitrogen (TN) in CA than CT, although only in Trabek it was seen as significantly different with a difference of 0.24 Mg (Table 2).
  - Both villages may have numerically higher TN in CA due to the addition of CJ which is a legume.
  - However, the generally lower CJ fresh biomass produced in Sratkat, due to the towering of trellised long bean, may have lead to low N addition compared to Trabek where cabbages were short statured.
- Soil depth – no effect
  - TN - regardless of treatment, were not significantly different between 0-10 cm and 10-20 cm in all Villages.
- No-interaction between soil depth and management
  - TN, regardless of treatment, were not significantly different between 0-10 cm and 10-20 cm in all Villages.

Table 2. Comparison of Total Nitrogen in Conservation Agriculture and Conventional Tillage in Research Sites, Siem Reap, Cambodia

Production Management	-----------O' village---------			----------Sratkat village-----			---------Trabek village-------		
	---------Depth---------			---------Depth---------			---------Depth---------		
	0-10 cm	10-20 cm	Mean	0-10 cm	10-20 cm	Mean	0-10 cm	10-20 cm	Mean
	-----------------Total Nitrogen (Mg ha^{-1}) -----------------								
CA	0.74±0.12	0.85±0.22	0.79±0.17	0.96±0.25	0.92±0.13	0.94±0.18	1.15±0.16	1.07±0.14	1.11±0.14^a
T	0.93±0.32	0.87±0.30	0.90±0.28	0.92±0.16	0.87±0.18	0.90±0.15	0.96±0.09	0.79±0.08	0.87±0.12^b
Mean	0.83+0.23	0.860.24		0.94±0.19	0.90±0.14		1.05±0.16	0.93±0.18	
Sources of Variation	*F*-value	*p*		*F*-value	*p*		*F*-value	*p*	$LSD_{0.10}$
Block	11.84	<0.00***		8.73	<0.01**		1.91	0.22^{ns}	
Management (M)	1.33	0.29^{ns}		0.46	0.52^{ns}		13.47	0.01**	0.12
Depth (D)	0.56	0.48^{ns}		0.46	0.52^{ns}		3.46	0.11^{ns}	
M*D	1.03	0.34^{ns}		0.02	0.88^{ns}		0.43	0.53^{ns}	

$^{***}p \leq 0.01$; $^{**}p \leq 0.05$; $^{*}p \leq 0.10$; ^{ns}Not significant; CA=Conservation agriculture; T=Conventional tillage
Means under each column with different letters are significantly different.

- Soil Respiration of CA was significantly greater by 19.7 CO_2-C per ha^{-1} day^{-1} than with CT (Table 3). When adjusted to the same soil moisture content and temperature, CA and CT difference was not significant.
  - This May indicate higher soil organic matter decomposition
  - May also indicate higher biological activity from soil organism or plants roots
  - In reference to an index by Soil Quality Institute[10] CA's values fall in the mid range of an 'ideal soil activity' while CT fall along the border between "ideal soil activity' and 'medium soil activity'.
    - Ideal soil activity = 'soil is at an ideal state of biological activity and has adequate soil organic matter and active populations of microorganisms'.
    - Medium soil activity = 'the soil is approaching or declining from an ideal state of biological activity.'
- CA Soil temperature was 2°C lower than fully exposed soil of CT.
  - Due to presence of cover crops (Rice mulch at 8 cm thick or 15 Mg ha^{-1})
- Soil Water content after 18-24 hours from uniform irrigation
  - The soil volumetric water content (%VWC) and percent water-filled pore space (%WFPS) were significantly higher in CA compared with T, which may be due to the mulch that acted as barriers from solar radiation, wind, and the impact of water from irrigation that may seal the soil pores due to crust formation, if uncovered, during the dry season.

Table 3. The Effect of CA and T on field gathered soil quality parameters.

			----------Field Measured Soil Quality Parameters--------		
Production Management	Actual Soil Respiration Kg CO_2-C per ha^{-1} day^{-1}	Soil Respiration (adjusted to 25 °C and 60% WFPS)	Temperature (°C)	Volumetric water content (%)	Water filled pore space (%)
Conservation Agriculture	55.9±4.8^a	84.05±40.8	30.4±2.0^a	20.0±11.9^a	41.4±23.3^a
Conventional Tillage	36.2±13.5^b	59.9±51.3	32.4±2.3^b	15.7±8.6^b	33.2±19.0^b
Sources of Variation					
Block	1.29^{ns}	6.8*	9.4**	18.1***	18.4***
Management	13.0*	3.2^{ns}	12.7**	5.0*	4.4*
$LSD_{(0.10)}$	11.03		1.1	3.9	7.9

$^{***}p \leq 0.01$; $^{**}p \leq 0.05$; $^{*}p \leq 0.10$; ^{ns}Not significant
Means with different letters under each column are significantly different

Conclusion

Short term soil quality test revealed that CA may have improved SOC in comparison to CT, provided that covercrops are grown in-situ in addition to the main crop roots being left on the ground. This increase in SOC may have increased actual soil respiration in CA. Soil temperature was reduced in CA compared to CT. Soil moisture retention was greater in CA compared to CT.

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