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Effects of Cropping Systems on Selected Soil Structural Properties and Crop Yields in the *Lam phra phloeng* Watershed-Northeast Thailand

Mohammad G. Azam, Micheal A. Zoebisch and Kanchana S. Wickramarachchi
Agricultural Systems and Engineering, Asian Institute of Technology, Thailand

Abstract: We conducted this study in Northeast Thailand (UTM coordinates 0795295, 1601006) to identify the degree of influence of four popular cropping systems (maize-maize, mungbean-maize, cassava and maize-fallow) and two of their relevant husbandry practices (residue management and tillage direction) on the deterioration of selected soil structural properties and the ultimate effect on crop yields. A number of soil structural properties were measured in both top and sub soil. The status of selected properties was evaluated under each of the cropping systems as well as husbandry practices through *in situ* and laboratory soil assessments. Mungbean-maize and cassava systems were found to be superior to maize-fallow and maize-maize systems in structural quality of the topsoils. Mungbean-maize system reported to have the highest value for soil organic matter. Residue management and tillage direction significantly affected only root density and soil shrinkage respectively. None of selected subsoil structural properties were significantly influenced by any of the cropping systems. Mungbean-maize and maize-fallow systems have significantly higher average and second crop yields over the maize-maize system.

Key words: Cropping systems, crop husbandry practices, soil structural properties, crop yields

INTRODUCTION

In Asia, especially in the developing countries, intensification of agricultural production systems has become a widespread practice through either increasing the number of cropping cycles within an agricultural year, or using new and short-duration hybrid crop varieties. These cropping systems seek more intensive husbandry practices, which often seem to be inappropriate from sustainable resource management point of view.

Increasing pressure on land and inappropriate land use practices has led to marked losses in soil fertility (Bruce *et al*., 1998) and SOM which leads to the degradation of soil structure. Soils with weak or degraded structure lose the ability to absorb, store, redistribute and release water. This leads to a decrease in soil-water availability and an increase in surface runoff and hence soil erosion that removes the fertile topsoils (Hauser *et al*., 2002; Nielsen and Zoebisch, 2001; Zoebisch and De Pauw, 2002). This degradation has an adverse effect on agricultural production and the ecology in general (Amor, 2000).

Any type of cropping does have effects on the soil quality (i.e., all chemical, physical and biological soil properties and processes). These effects can be either favorable or unfavorable, enhancing or deteriorating the soil properties. For example, continuous sugarcane monocropping for 30 years compared with undisturbed forest has resulted in a 3-fold reduction of available water content and a considerable reduction of wet aggregate stability (Caron *et al*., 1996); intercropping of maize with legumes (*Mimosa invisa*) has led better protection against soil erosion and higher grain yields than the conventional continuous monocropping of maize (Suwanarit *et al*., 1999). The same cropping system under different soil and crop management practices can result marked differences in soil characteristics. Tillage operations leaving crop residues on the soil surface-such as no-tillageand in-row sub-soiling etc. can reduce or eliminate surface crusting, increase infiltration, lower bulk density, improve porosity and soil strengthand consequently reduce surface runoff and soil loss while increasing crop yield (Cassel *et al*., 1995; Lal *et al*., 1994). The same soil manipulation practice at different intensities may have variable effect on the soil-pore system and consequently hydraulic conductivity and other physical soil characteristics (Horn *et al*., 2003).

Thailand has become one of the Asia's largest food-exporting countries (Wilson, 2002) through intensification of market oriented cropping systems. Maize and cassava based rotations of annual crops are the major cropping systems in the *Lam phra phloeng* watershed, Nakhon Ratchasima, Northeast Thailand (Cho and Zoebisch, 2003). For more than 30 years, maize

Corresponding Author: Mohammad G. Azam, Agricultural Systems and Engineering, Asian Institute of Technology, Thailand

has been the dominant crop (Cho and Zoebisch, 2003). Often it is cultivated twice a year in most of the area without a fallow period for regeneration of the soils. Cassava a root crop is also produced on a large scale on sloping, erosion prone lands. The intensification of these cropping systems is fueled by the excessive use of inorganic fertilizers, herbicides and pesticidesand intensive tillage operations, which have become standard practice in the area and other inappropriate crop and soil management practices (Cho and Zoebisch, 2003). In most cases, the farmers plow their sloping lands (2-12% slope) along the slope using heavy machinery. After harvest, the fields are cleared of the crop residues, usually by either burning or removing them from the field. They are usually not incorporated into the soil, with few exceptions. Theses practices in the long run have led to a deterioration of soil structural properties and SOM as well (Lal *et al.*, 1994). It is also questioned whether those cropping systems significantly influence the final yields of crops (Huggins *et al.*, 2001; Katsvairo *et al.*, 2002; Arshad *et al.*, 2002; Nielsen *et al.*, 2002).

The main objective of the study was to identify the degree of influence of different cropping systems and their main relevant husbandry practices on the deterioration of soil structural properties and the ultimate effect on crop yield in the *Lam phra phloeng* watershed.

MATERIALS AND METHODS

Site descriptions: The study was conducted at Wang-Mi Sub-District, Wang Nam Keo District, Nakhon Ratchasima Province and Northeast Thailand in the year 2004. The area is located in the central part of the Lam Phra Phloeng watershed at UTM coordinates: 0795295, 1601006 (Eastern stream of the Kao Yai National Park). The study area had an average elevation of~500 m amsl, undulating with a slope range from 2% to11%. The area receives an average annual rainfall of about 1,100 mm with 80-120 rainy days (TAO, 2000). The highest rainfall occurs in September-October (around 100 mm month^{-1}) and the minimum in March (around 50 mm month^{-1}). Most of the soils in the area are similar in their characteristics and with high clay contents, occurs in Muek Lek Series (LDD, 2002). Generally the top soil (0-30 cm) is dusky red (10R 3/3) in color with clay texture of 15.4, 19.9 and 64.6% sand, silt and clay respectively. The top soil is sticky and plastic with fine and granular aggregates. The sub-soil (31-100 cm) is having dark reddish brown (2.5YR 3/4) color with clay texture of 21, 12 and 67% sand, silt and clay respectively. Sub-soil is sticky and plastic with medium sized sub-angular aggregates.

Cropping system information and site selection: Data and information regarding cropping systems as well as land and crop-management practices were obtained through an interview-based survey using Participatory Rural Appraisal (PRA) and questionnaire techniques (Table 1). Only the fields have been cultivated for more than 10 years with the same crops (selected crops were maize, mungbean and cassava) and within the selected soil series, were kept in the final sampling. After the identification and characterization of the land-use history, four main cropping systems were selected within 37 cases (sites). They are (i) maize-maize (8 cases), (ii) mungbean-maize (10 cases), (iii) cassava (9 cases) and (iv) maize-fallow (10 cases). Two husbandry practices, namely residue management and tillage directions, were selected. Nineteen cases for residue burning (maize-maize 3 cases, mungbean-maize 6 cases, cassava 1 case and maize-fallow 9 cases) and 18 cases for incorporating

Table 1: Important crop management practices under four cropping systems

	Cropping systems				
		Mungbean-maize			
Practices	Maize-maize	Mungbean	Maize	Cassava	Maize-fallow
Land preparation					
Method	Tractor	Tractor	Tractor	Tractor	Tractor
Primary tillage	3 disk	7 disk	3 disk	3 disk	3 disk
Secondary tillage	7 disk	none	7 disk	none	7 disk
Tillage depth (cm)	10 to 30	10 to 30	10 to 30	10 to 30	10 to 30
Planting					
Methods	Sowing-machine	Manual broadcast	Sowing-machine	Manual planting	Sowing-machine
Dates	*March-April; July-August	March-April	July-August	March-April	July-August
Seed variety	Cargil (949,919,717)	Kampangsaen	Cargil (949,919,717)	Local, KU-variety	Cargil (949,919,717)
Fertilizer programs					
Nitrogen (kg ha^{-1})	156.25	-	162.50	125.00	250.00
P_2O_5 (kg ha^{-1})	121.50	-	62.50	31.25	125.00
K_2O (kg ha^{-1})	18.75	-	12.50	6.25	0
Harvesting method	Manual	Manual	Manual	Manual	Manual

*: First crop planted in March-April and second crop in July-August

(maize-maize 5 cases, mungbean-maize 4 cases, cassava 8 cases and maize-fallow 1 case) were selected. Up and down tillage (against the slope) has 25 cases (maize-maize 7 cases, mungbean-maize 4 cases, cassava 8 case and maize-fallow 6 cases) and along the contour has 12 cases (maize-maize 1 case, mungbean-maize 6 cases, cassava 1 case and maize-fallow 4 cases). The average crop yields were measured from the farmer's interviewed data. Since maize is the major component of three systems, only it is used in crop yield comparison.

Soil sampling, processing and analyses: Soil samples were collected from all identified sites after crop harvesting. Two sets of samples (bulk samples and core samples) were collected from Ap horizon and rooted subsoil. The bulk samples with 3 replications in each case have been used to determine particle-size distribution, aggregate stability, shrinking-swelling properties and SOM. Undisturbed core samples, with 3 replications in each case, were obtained to determine moisture retention characteristics, bulk density and porosity. In laboratory analysis soil water content was measured by gravimetric method (Gardner, 1986). Particle size distribution was analyzed by pipette method (Rosewell, 2002; Sheldrick and Wang, 1993). Bulk density (ρ_b) and the porosity (Φ) were tested using core-sampling method (Cresswell and Hamilton, 2002). Aggregate stability and soil shrinkage were measured by wet sieving method (Patton *et al.*, 2001) and Linear Shrinkage Box (LS_{std}) method (McGarry, 2002) respectively. SOM was analyzed by Walkey-Black method (Nelson and Sommers, 1982). All the above parameters were measured for Ap horizon soil and only SOM, bulk density and shrinkage for sub soil.

***In situ* soil assessment:** For Ap horizon soil of each selected field, a comprehensive soil-profile description (root density, dominant pore size, pore distribution frequency, aggregate shape, aggregate size, aggregate grade, packing density etc.) was made according to the FAO-UNESCO soil-profile description guidelines (FAO, 2002) and the guidelines of the Soil Survey of England and Wales (1973) with 3 replications for each parameter in each case. Soil infiltration characteristics were measured on each selected field with five replications by a single ring method (Bagarello *et al.*, 2004) with 5 replications in each case.

Statistical analyses: Standard Analysis of Variance (ANOVA) at different levels of significance ($p \leq 0.01$, 0.05 and 0.10) were applied to test the differences between soil properties and subsequent crop yields using SPSS statistical package. Student's t-test was applied at $p \leq 0.05$ level to test the significance of differences between the land husbandry practices using MS Excel.

RESULTS AND DISCUSSION

Cropping system effects on the top soils: The data set of the Ap horizon illustrates that some of the parameters are significantly varied among cropping systems that would be the influence cropping systems. Five of the studied parameters such as shrinkage ($p \leq 0.05$), porosity ($p \leq 0.10$), packing density ($p \leq 0.05$), bulk density ($p \leq 0.10$) and % sand in non-dispersed method ($p \leq 0.10$) significantly show the best values in the cassava system in terms of soil structural characteristics and two parameters namely, pore size ($p \leq 0.05$) and SOM ($p \leq 0.05$) show the poorest

Table 2: Some hydraulic qualitative parameters of Ap horizon soil in four cropping systems

		Cropping systems				
Desired categories	Soil properties	Maize-maize	Mungbean-maize	Cassava	Maize-fallow	p>F
More is better	RD	3.50 ± 0.54^{b}	4.30 ± 0.48^{a}	3.89 ± 0.60^{ab}	4.20 ± 0.63^{ab}	0.01
	PS	1.13 ± 0.35^{ab}	1.30 ± 0.48^{a}	1.00 ± 0.00^{b}	1.00 ± 0.00^{b}	0.05
	PD	1.38 ± 0.74^{b}	2.20 ± 0.92^{a}	1.89 ± 0.60^{ab}	2.10 ± 0.88^{ab}	0.05
	Asi	2.00 ± 0.54^{a}	1.80 ± 0.63^{ab}	1.89 ± 0.33^{ab}	1.40 ± 0.70^{b}	0.05
	SOM (%)	2.40 ± 0.28^{b}	2.80 ± 0.41^{a}	2.40 ± 0.39^{b}	2.63 ± 0.35^{ab}	0.05
	Shr (%)	12.91 ± 2.37^{ab}	11.72 ± 1.87^{b}	14.39 ± 2.19^{a}	12.13 ± 1.57^{b}	0.05
	P (%)	53.73 ± 4.67^{b}	53.55 ± 5.90^{b}	56.93 ± 2.99^{a}	56.79 ± 2.72^{a}	0.10
	ASh	1.63 ± 0.92	1.50 ± 0.71	1.44 ± 0.53	1.70 ± 0.68	NS
	AG	3.25 ± 0.46	2.90 ± 0.32	3.11 ± 0.33	3.30 ± 0.82	NS
	IR (mm h^{-1})	372.60 ± 183.2	495.00 ± 127.6	457.60 ± 174.6	388.60 ± 169.3	NS
	SWC (g g^{-1})	69.70 ± 7.332	65.72 ± 7.87	64.79 ± 6.61	66.73 ± 5.21	NS
	WS (%)	41.42 ± 14.09	39.12 ± 13.99	45.89 ± 19.10	44.07 ± 17.07	NS
Less is better	PkD	2.00 ± 0.00^{a}	1.60 ± 0.52^{ab}	1.44 ± 0.53^{b}	1.50 ± 0.53^{b}	0.05
	BD (g cc^{-1})	1.23 ± 0.12^{a}	1.23 ± 0.16^{a}	1.14 ± 0.08^{b}	1.15 ± 0.07^{b}	0.10
	Sa (nd) (%)	92.61 ± 2.56^{ab}	92.18 ± 1.97^{ab}	91.16 ± 2.55^{b}	93.01 ± 1.65^{a}	0.10

Different superscripted letter(s) show the level of significance at p = 0.01; p = 0.05; p = 0.10; NS = Non-significant at the level of p = 0.10, No. of cases in Maize-Maize = 8; No. of cases in Mungbean-Maize = 10; No. of cases in Cassava = 9 and No. of cases in Maize-Fallow = 10, RD = Root Density; PS = Dominant pore size; PD = Pore Distribution/frequency; ASh = Aggregate shape; Asi = Aggregate size; AG = Aggregate Grade; PkD = Packing density; BD = Bulk Density; P = Porosity; SOM = Soil Organic Matter; IR = Infiltration Rate; SWC = Soil Water Content at field capacity; Sa (nd) = Sand in non dispersed method; Shr = Shrinkage; WS = Water aggregate stability more is better = When the higher value of a parameter is desire; less is better = When lower value of a parameter is desired conditions in the topsoils. The case is similar to the mungbean-maize system where root density ($p \leq 0.01$), pore size ($p \leq 0.05$), packing density ($p \leq 0.05$) and SOM ($p \leq 0.10$) show the best values. However, three parameters namely shrinkage ($p \leq 0.05$), porosity ($p \leq 0.10$) and bulk density ($p \leq 0.10$) were found to have the poorest in mungbean-maize system. Thus, these two systems show a significantly distinguishable trend in structural behavior from the other two systems; especially from the maize-maize system where six parameters show poorest status while only one shows the best value (Table 2).

Mungbean-maize system shows significantly ($p \leq 0.05$) highest value of pore size from the cassava and maize-fallow and pore distribution ($p \leq 0.05$) frequency from the maize-maize system. These may be due to higher rate of biological activities in the soil of this system. SOM, the central component of the soil food web (Kleinhenz and Bierman, 2001), also shows significantly ($p \leq 0.05$) highest value for this system from the maize-maize and cassava systems, supporting the assumption of this study. Root density ($p \leq 0.01$) is another parameter that goes along with the above parameters. Root penetration and root density is related to pore size and continuity, availability of SOM as well as the biological activity (Allison, 1973). The breakdown of 'active' organic residues produces long polysaccharides (sugars) that are gummy and bind soil particles into stable aggregates that resist compaction. Aggregation and the activity of earthworms, burrowing insects and plant roots create channels that aid water infiltration, aeration and drainage (Kleinhenz and Bierman, 2001). The highest infiltration rate was measured in the mungbean-maize system which might be the result of a better vertical connectivity and continuity of the macrospores (Hangen *et al.*, 2002). On the other hand, the lowest infiltration rate was measured in the maize-maize system; might probably due to the lowest SOM content and a more intense machinery travel causing soil compaction (Hageman and Shrader, 1979). However, infiltration characteristic were not significantly ($p \leq 0.10$) dependent on the cropping systems.

Total porosity did not vary significantly (significant only at $p \leq 0.10$) with the cropping systems as concluded by Katsvairo *et al.* (2002). Most probably, the reason is the use of the same tillage implements and similar tillage intensity (Table 1). The cassava system shows the lowest mean bulk density and hence the highest total porosity. This is probably due to the intense loosening of the soil during harvest by pulling out the roots. Less machinery travel (Table 1) is another probable cause for the lowest measured bulk density (Hageman and Shrader, 1979). However, soil disturbance is still not in alarming situation for cassava production told by the farmers. This fact could be justified by the significantly higher shrinking-swelling properties ($p \leq 0.05$), which is very important for reconstruction and recuperation of degraded soil structure (Pillai-McGarry and Collis-George, 1990; Pillai-McGarry and McGarry, 1999). Both the maize-maize system and the mungbean-maize system have two cropping cycles per year that require at least two primary tillage and one to two secondary tillage operations (Table 1). This may be the reason for the highest bulk density and the lowest total porosity in these two systems (Hageman and Shrader, 1979).

The maize-maize system scored significantly highest mean values of aggregate size ($p \leq 0.05$) from the maize-fallow and packing density ($p \leq 0.05$) from the cassava and maize-fallow systems. No obvious reason was found for the larger aggregate size. However, the high packing density also points to a high bulk density. High machinery travel is the probable reason of showing higher soil density (Hageman and Shrader, 1979). Mean soil water content (at field capacity) was also highest for this system but not significantly ($p \leq 0.10$) distinguishable from other systems. The probable reason would be the larger aggregate size in this system with lots of inter aggregate pores, which is important for increased water retention (Dexter, 2003).

Cropping husbandry effects on the top soils: No significant differences were found among the soil parameters of Ap horizon of the soils used for assessing soil structural status for the area with two different residue management practices except for root density ($p \leq 0.05$) (Table 3). One possible reason of higher score for root density under residue burning is that the practice is mostly limited to the maize based systems and maize has a fibrous root system which is denser than that of cassava.

In the tillage directions, a similar trend was found as with residue management (Table 3). Only the shrinking-swelling property, in across the contour (up-down) system, shows significantly ($p \leq 0.05$) higher value (13.2%) than in along the contour system (11.7%). Across the contour tillage operation may be responsible for deposition of higher clay particle in the soils and hence higher shrinkage. Other properties do not show any significant differences.

Subsoil properties: None of the selected cropping systems had significant effect (positive or negative) on SOM content, density and shrinking-swelling properties of rooted subsoils (Table 4). The non-significant differences ($p \leq 0.10$) indicate that this soil layer is

Table 3: Some hydraulic qualitative parameters of Ap horizon soil under different residue management practices and tillage operations

Soil properties	Residue# Burning	Residue# Incorporating	t-Stat	Significance levels	Tillage directions# UD	Tillage directions# AC	t-Stat	Significance levels
RD	4.21±0.54	3.78±0.65	2.21	*	3.88±0.60	4.25±0.62	1.71	NS
PS	1.05±0.23	1.17±0.38	1.09	NS	1.08±0.28	1.17±0.39	0.69	NS
PD	2.00±0.88	1.83±0.79	0.61	NS	1.80±0.82	2.17±0.84	1.26	NS
Ash	1.53±0.70	1.61±0.70	0.37	NS	1.56±0.71	1.58±0.67	0.10	NS
Asi	1.74±0.73	1.78±0.43	0.21	NS	1.72±0.54	1.83±0.72	0.49	NS
AG	3.26±0.65	3.00±0.34	1.40	NS	3.08±0.49	3.25±0.62	0.31	NS
PkD	1.63±0.54	1.61±0.50	0.13	NS	1.64±0.49	1.58±0.52	0.32	NS
BD (g cc^{-1})	1.18±0.14	1.19±0.10	0.15	NS	1.20±0.13	1.16±0.07	1.33	NS
P (%)	55.40±5.10	55.20±3.70	0.15	NS	54.70±5.0	56.40±2.6	1.33	NS
SOM (%)	2.60±0.38	2.50±0.41	0.64	NS	2.50±0.37	2.70±0.40	1.49	NS
IR (mm h^{-1})	450.50±167.8	409.70±163.3	0.75	NS	423.30±169.6	446.10±159.8	0.40	NS
SWC (g g^{-1})	67.70±7.0	65.50±6.5	0.89	NS	66.00±7.8	67.90±3.6	0.91	NS
Sa (nd) (%)	92.30±2.0	92.20±2.5	0.24	NS	92.50±2.4	91.80±1.7	1.02	NS
Shr (%)	12.30±2.0	13.30±2.3	1.41	NS	13.20±2.3	11.70±1.5	2.52	*
AS (%)	42.70±14.3	42.50±17.6	0.44	NS	44.90±17.4	37.80±10.6	1.54	NS

* = Significant, NS = Non-significant at the level of p = 0.05, No. of cases in residue burned = 19; No. of cases in residue incorporated = 18, No. of cases up and down tillage = 25; No. of cases along the contour = 12, # = Mean values followed by the respective standard deviations have been used in the table, UD = Up and down; AC = Along the contour; RD = Root Density; PS = Dominant pore size; PD = Pore distribution/frequency; ASh = Aggregate shape; Asi = Aggregate size; AG = Aggregate Grade; PkD = Packing Density; BD = Bulk Density; P = Porosity; SOM = Soil Organic Matter; IR = Infiltration Rate; SWC = Soil Water Content at field capacity; Sa(nd) = Sand in nondispersed method; Shr = Shrinkage; AS = Water aggregate stability

Table 4: Some soil properties of the sub soil under four cropping systems

Sub soil properties	Cropping systems: Maize-maize	Mungbean-maize	Cassava	Maize-fallow
SOM (%)	1.73±0.35	1.81±0.27	1.66±0.35	1.50±0.43
BD (g cc^{-1})	1.27±0.05	1.26±0.07	1.25±0.08	1.22±0.07
Shrinkage (%)	17.16±5.07	14.71±2.50	16.50±1.28	16.00±2.02

Table 5: Yields (t ha^{-1}) of maize under three different cropping systems

Cropping systems	First crop	Second crop	Average
Maize-Maize	4.22 ±1.14^{b} (8)#	4.69±1.29^{b} (8)	4.46±1.21^{b} (16)
Mungbean-Maize	-	6.59±0.65^{a} (9)	6.59±0.65^{a} (9)
Fallow-Maize	-	6.33±1.28^{a} (9)	6.33±1.28^{a} (9)

Different letter(s) show the levels of significance along the column at p = 0.05, # = Values in the brackets show the number of cases

untouched and undisturbed by the normal farming practices. However, excess tillage operation in maize-maize system may cause higher clay particle leaching down and hence higher BD and soil shrinkage comparing to mungbean-maize and maize-fallow systems.

Yields differences: It is widely accepted that cropping systems significantly influence the final yields of crops (Huggins *et al.*, 2001; Katsvairo *et al.*, 2002; Arshad *et al.*, 2002; Nielsen *et al.*, 2002). Mungbean-maize (6.59 ton ha^{-1}) maize-fallow (6.33 ton ha^{-1}) have significantly ($p \leq 0.05$) higher average and second crop yields from the maize-maize system (Table 5). For the second crop the planting dates, crop variety used and general management practices are almost similar. However, maize-fallow system receive higher doze of nitrogen and phosphorus comparing to other two systems (Table 1). Yield difference of mungbean-maize system that could be justified by higher SOM content by the inclusion of mungbean a legume crop (Arshad *et al.*, 2002) as well as many other favorable soil parameters in the system (Table 2). For maize-fallow system the higher doze of fertilizer, fewer favorable soil parameters as well as a fallow period would result into higher yield. Thus, mungbean-maize and maize-fallow systems give higher yields than the maize-maize system (Cho, 2003).

CONCLUSIONS

The results show that cropping systems have both enhancing and deteriorating effects on soil structural properties of the topsoils and the average crop yield as well in the studied area. Shrinkage, porosity, packing density, bulk density and sand in non dispersed method, significantly showed better structural quality in the cassava system while pore size and SOM showed deteriorating conditions. Likewise in mungbean-maize system root density, dominant pore size, pore distribution/frequency and SOM showed significantly better values though shrinkage, porosity and bulk density are in weakened situation.

Packing density, bulk density and porosity were proved to be significantly better in maize-fallow system where as pore size; aggregate size, shrinkage and % sand are found deteriorated. Maize-maize system had poorest soil structural status having six parameters with poorer values and only one with better situation. Thus, mungbean-maize and cassava systems show a significantly distinguishable trend in structural behavior from the other two systems, especially from the maize-maize system. Only root density shows significant difference for residue burning system, which is mainly practiced with the cropping system of maize that is a fibrous root system crop. Tillage directions significantly influence only the soil shrinkage by the depositing higher clay particle in across the contour system. Subsoil structures were found undisturbed and insignificantly affected by the cropping systems.

Both mungbean-maize and maize-fallow systems have significantly higher average and second crop yield. Significantly higher level of SOM possibly by the inclusion of mungbean and comparatively higher number of favorable soil parameter would result higher yield in mungbean-maize. On the other hand, maize-fallow system would have higher yield due to higher doze of fertilizer with some favorable soil parameters as well as a prolonged fallow period. So, it would be wise decision by the farmers to move from maize-maize as well as maize-fallow systems to mungbean-maize to sustain better soil structure and at the same time higher yield of their crops.

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