Research article

Comparison of Soil Properties of Farmlands Applied with Organic and Inorganic Fertilizers in Kampong Cham Province, Cambodia

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Abstract In Cambodia, soil capability for rice production in lowlands has been almost documented, but only little is known about the properties of upland soils for growing non-rice crops. Current agricultural land use practices together with severe climatic conditions and population pressure have led to soil degradation, loss of soil fertility which declining crop yield and increase the risk of malnutrition. Therefore, the objectives of this study were 1) to compare the soil properties of farmlands applied organic and inorganic fertilizers, 2) to measure the organic fertilizer dependence in Samraong and Baray Communes. The questionnaire survey was conducted and farmer representatives were interviewed. Soil samples were collected from 20 different locations. Soil samples were analyzed for its pH, Electrical conductivity (EC), organic matter, total nitrogen (T-N), total phosphorus (T-P), calcium (Ca^{2+}), potassium (K^{+}), sodium (Na^{+}), water content, and permeability, and the Pearson coefficient correlation was used for the statistical analysis. Organic fertilizer dependence was classified into 3 categories not dependent, moderately dependent and highly dependent, 40.0%, 30.0%, and 30.0%, respectively. The results of statistical analysis showed that in Samraong Commune there was no trend detected, despite in Baray Commune there was positive trend detected between organic fertilizer dependence and soil properties.

Keywords soil properties, fertilizers, organic, inorganic, dependency

INTRODUCTION

Cambodia is located in the southern portion of Indochina peninsula, and sheared its borders with Thailand, Laos and Vietnam. The total land area of Cambodia is 181,035 km^2 and current population is 16.2 million in which only 78.3% is living in rural areas. Agricultural production in Cambodia is concentrated in the northwestern districts bordering Thailand, on the central plains surrounding the Tonle Sap Lake and its river systems, along the Mekong River towards the Mekong delta. The total land use area under major agricultural crops was about 4.5 million ha (MAFF, 2012). Agricultural lands could be categorized into two distinct topographical regions lowlands and uplands. Lowland soils mainly support rice framing interspersed with field crops, vegetable gardens and fruit trees. Upland soils are mainly used for rubber (*Hevea brasiliensis*) plantations, maize (*Zea mays*), cassava (*Manihot esculenta*), soybeans (*Glycine max*), mug-beans (*Vigna radiata*), peanuts (*Arachis hypogaea*), sesame (*Sesamum indicum*), sugarcane (*Saccharum officinarum*), and fruit trees (Ministry of Agriculture, Forestry and Fisheries, Cambodia, 2012). Moreover, the farming system in Cambodia is normally based on the application of chemical

fertilizers, chemical pesticide, fungicide and herbicide (FAOSTAT, 2016). Fertilizers play a key role in agriculture production, cultivation of a major crop that rely on the use of high rates of inorganic fertilizers continuously for several years, often lead to unsustainability in production and also pose threat to the environment (Smith et al., 1990), thought chemical fertilizers are high in nutrient contents and are rapidly taken up by plants but relatively expensive. Excessive use of fertilizers results in various problems, such as nutrients loss, surface water and groundwater contamination, soil acidification, reductions in useful microbial communities, and increase in sensitivity of harmful insects (Chen J.H., 2006). Recent year, with the support from the government and non-governmental organization (NGOs), many Cambodian farmers realized and looked for a better practice which could harmonize with natural environment and human health. There were several practices carried out to move forwards from the used of inorganic fertilizers to promote on the application of organic fertilizers such as green manure, compost, and bio-liquid fertilizer in some provinces of Cambodia. With the use of organic fertilizers could eliminated and minimize the use of inorganic fertilizers as well as improved on soil, water and environmental quality. By the several practices that carried to promote the use of organic fertilizers in order to meet the requirement of nutrients in soil, so each practice may contribute to difference of positive and negative effect attributes to farmlands.

OBJECTIVES

The objectives of this study were 1) to compare soil properties of farmlands applied organic and inorganic fertilizers, and 2) to measure organic fertilizer dependence in Samraong and Baray Communes, Kampong Cham Province, Cambodia.

METHODOLOGY

Study Site

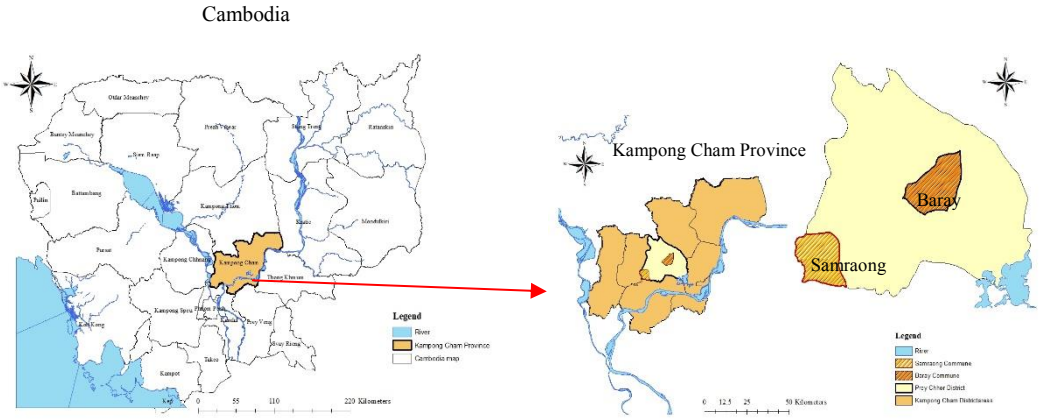

Fig. 1 Map of the study areas

Kampong Cham Province is located in the central region of Cambodia. The population is 1.6 million. Prey Chhor District is located in Kampong Cham Province and it's divided into 15 communes and 176 villages. The major soil types in this areas are brown hydromorphics, regurs and cultural hydromophics (Kampong Cham Administration, 2010). Samraong and Baray Communes were selected for this study. In Samraong and Baray Communes the population were around 8,123 and the total number of families were 1,714 and 11 villages and 10,637 and the total number of families were 2,446, and 13 villages, respetively. Farmers in both communes were mostly smallholder farmers with less than 1 ha of cultivated agricultural land (CDB, 2010). In Samraong and Baray Communes the main economic activity of farmers are rice cultivation in low land and vegetables in upland fields are also cultivated (ERECON, 2009). In order to increase the productivity of farmland local farmers tend to use high amount of chemical fertilizers. The number

of families using chemical fertilizers was around 1,587 in Samraong Commune and 1,479 in Baray Commune. There was a project implemented to promote sustainable agriculture in Samraong Commune by Japan International Cooperation Agency (JICA) from 2011 to 2016. The target group comprised of 450 households in Samraong Commune. A similer project was implemented in Baray Commune to promote organic farming through composting and liquid fertilizer by Ministry of Agriculture, Forestry and Fisheries (MAFF), Japan from 2006 to 2009, 45 households were the target group.

Questionnaire Survey

Questionnaire survey was conducted in Samraong and Baray Communes. Farmer representatives were interviewed. The questionnaire included questions about general information, economical condition and agricultural condition as shown in Table 1.

Table 1 The contents of questionnaire survey for the field activities

Category	Details
General information	Name, Age, Gender, Level of education, Occupation
Economical condition	Working condition, Land areas, Crops cultivation, Labor use in agriculture, Cost of fertilizers
Agricultural condition	Problems in agricultural land, Kinds of agro-chemicals, Kinds of livestock

Soil Analysis

Soil samples were collected from 20 different locations. Soil sampling sites are shown in Fig. 2. There were 20 disturbed and 20 undisturbed soil samples were collected from Samraong and Baray Communes in August, 2017. Disturbed soil samples were used to analyze for its pH, EC, water content, organic carbon, total nitrogen, total phosphorus, particle size distribution, calcium, potassium and sodium. Undisturbed soil samples were analyzed for its permeability and bulk density. The experiment was conducted in September, 2017. The details of soil analysis are shown in Table 2.

Table 2 Soil indicators for the laboratory activities

Physical properties	Water content	Particle size distribution	Organic matter	Permeability
Methods	Gravimetric method	International pipette method	Ignition loss	Saturated hydraulic conductivity (Ksat) method
Chemical properties	pH	EC	T-N and T-P	Ca^{2+}, K^{+}, and Na^{+}
Methods	Dilution	Dilution	Absorption spectroscopy	Portable absorption spectrophotometer

EC: Electrical conductivity, T-N: Total nitrogen, T-P: Total phosphorus, Ksat: Saturated hydraulic conductivity, Ca^{2+}: Calcium, K^{+}: Potassium and Na^{+}: Sodium

Organic Fertilizer Dependence

Organic Fertilizer Dependence of the farmers in Samraong and Baray Communes was analyzed based on nitrogen application in organic and inorganic fertilizers during complete growing season. Total nitrogen application by farmers was calculate using equation (1) and Organic fertilizer dependence was calculated using equation (2).

$$TN = A \times N / 100 \quad (1)$$

Where, TN is total nitrogen content (kg ha^{-1} yr^{-1}), A is the amount of fertilizers applied (kg ha^{-1}), and N is the percentage of nitrogen concentration of the fertilizers (%)

$$OFD = (ON_1 + ON_2 + ON_3 + \ldots + ON_n) \div (ON_n + IN_n) \times 100 \quad (2)$$

Where, OFD is Organic Fertilizer Dependence (%), ON_1 is nitrogen content in organic fertilizer (kg ha^{-1} yr^{-1}), ON_n is total nitrogen content in all the organic fertilizers application (kg ha^{-1} yr^{-1}), NI_n is total nitrogen content in all the inorganic fertilizers application (kg ha^{-1} yr^{-1}).

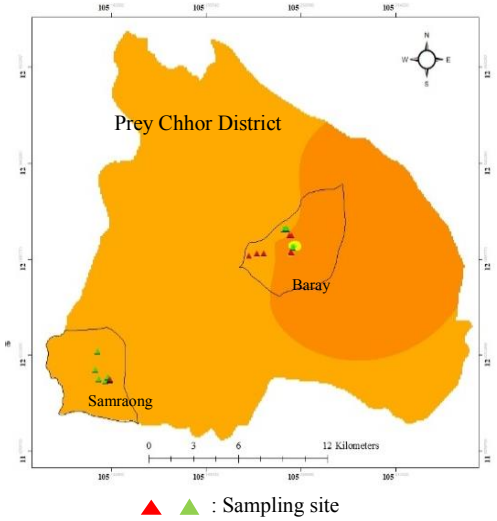

Fig. 2 Soil sampling sites

RESULTS AND DISCUSSION

Questionnaire Survey

The results from the questionnaire survey shown in Fig. 4 indicated that the representative farmers in the study areas has total cultivated agricultural lands about 0.5 to 1 ha. This cultivated land areas mostly used for the rice and vegetable cultivation activities in Samraong and Baray Communes.

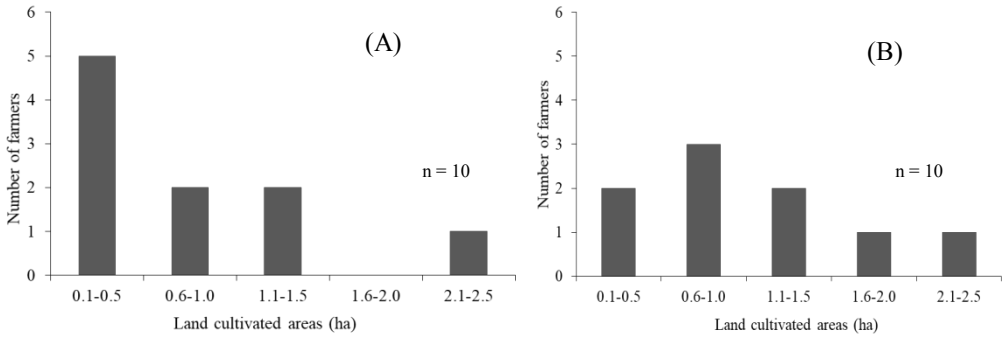

Fig. 3 Land cultivated areas from the responded farmers in (A) and (B)

Agricultural Condition

The result of agricultural condition were about the types of fertilizers used and the percentage of organic fertilizers dependence were shown in Table 3. As shown in Table 3 there were 4 types of commons fertilizers used including Urea, DAP, cow manures, and compost.

Table 3 Types of fertilizers used (kg/ha/year) from the responded farmers in Samraong and Baray Communes

Site	Urea (kg/ha/yr)	N (kg/ha/yr)	DAP (kg/ha/yr)	N (kg/ha/yr)	Cow manure (kg/ha/yr)	N (kg/ha/yr)	Compost (kg/ha/yr)	N (kg/ha/yr)	TN (kg/ha/yr)	OFD (%)
	N% (46%)		N% (18%)		N% (1.587%)		N% (1.086%)			
1	50	23	50	9	2000	31.6	1000	10.86	74.46	**57%**
2	100	46	100	18	25000	395	5000	54.3	513.3	**88%**
3	100	46	100	18	4000	63.2	4000	43.44	170.64	**62%**
4	100	46	100	18	3000	47.4	3000	32.58	143.98	**56%**
5	50	23	50	9	0	0	1500	16.29	48.29	34%
6	240	110.4	240	43.2	30	0.474	10	0.1086	154.1826	0%
7	20	9.2	100	18	100	1.58	0	0	28.78	5%
8	20	9.2	50	9	50	0.79	0	0	18.99	4%
9	500	230	250	45	0	0	0	0	275	0%
10	50	23	200	36	0	0	0	0	59	0%
11	200	92	0	0	1500	23.7	1500	16.29	131.99	30%
12	100	46	50	9	1500	23.7	1500	16.29	94.99	42%
13	40	18.4	200	36	500	7.9	500	5.43	67.73	20%
14	6	2.76	0	0	500	7.9	500	5.43	16.09	**83%**
15	0	0	16	2.88	1000	15.8	1000	10.86	29.54	**90%**
16	100	46	300	54	0	0	0	0	100	0%
17	100	46	200	36	0	0	0	0	82	0%
18	150	69	150	27	0	0	0	0	96	0%
19	30	13.8	30	5.4	0	0	0	0	19.2	0%
20	30	13.8	100	18	0	0	0	0	31.8	0%

N: Nitrogen, TN: Total nitrogen, OFD: Organic Fertilizer Dependence

Organic Fertilizer Dependence was calculated based on type of fertilizers, nitrogen concentration (N%) in fertilizers and amount applied. Average total nitrogen contents for cow manure were calculated based Maerere et al. (2001), Usman (2013), Sherrian (2016), Huang (2017) and average total nitrogen content for compost were calculated based on Obiamaka (2011), Sophark T et al. (2012), E-Sayed (2015), Sherrian (2016) and Merlyn (2017). Therefore, organic fertilizer dependence was classified into 3 categories as 'not dependent', 'moderately dependent' and 'highly dependent' at 40%, 30% and 30%, respectively as shown in Table 4.

Table 4 Organic fertilizer dependence categorized

Category	Dependence (%)	Farmer dependence (%)
No dependent	0	40.0%
Moderately dependent	0-50	30.0%
Highly dependent	50-100	30.0%

Correlation Matrix Tree Between Organic Fertilizer Dependence and Soil Properties

The correlation matric tree was used to compare the relationship between organic fertilizer dependence and soil properties. The results are shown in Figs. 4 and 5.

	Organic fertilizers dependence (%)	Inorganic fertilizers dependence (%)	pH	EC (ms/cm)	Permeability (mm/hr)	OM (%)	OC (%)	Total nitrogen (mg/kg)	Total phosphorus (mg/kg)	Potassium (mEq/L)	Calcium (mEq/L)	Sodium (mEq/L)
Organic fertilizers dependence	1											
Inorganic fertilizers dependence	-1**	1										
pH	-0.1798	0.1798	1									
EC	-0.3406	0.3406	0.4455	1								
Permeability	-0.3529	0.3529	-0.5505	0.0244	1							
OM	-0.5866	0.5866	0.7134*	0.4590	-0.3198	1						
OC	-0.5866	0.5866	0.7134*	0.4590	-0.3198	1.0000	1					
Total nitrogen	0.4307	-0.4307	-0.2028	-0.5617	-0.0128	-0.5875	-0.5875	1				
Total phosphorus	0.5645	-0.5645	0.2730	0.2698	-0.2325	0.0462	0.0462	0.0099	1			
Potassium	0.5887	-0.5887	-0.0128	0.0081	-0.1131	-0.2827	-0.2827	0.4158	0.6832*	1		
Calcium	0.3800	-0.3800	0.2849	-0.2413	-0.0974	-0.2165	-0.2165	0.4486	0.5034	0.4775	1	
Sodium	-0.4879	0.4879	0.6260	0.6138	-0.3794	0.5352	0.5352	-0.2176	-0.2347	-0.3357	-0.3041	1

*n= 10, r > 0.631897 significance level *P< 0.05, r > 0.764592 signifivance level **P< 0.01*

Fig. 4 Correlation matrix tree between Organic Fertilizer Dependence and soil properties in Samraong Commune

	Organic fertilizers dependence (%)	Inorganic fertilizers dependence (%)	pH	EC (ms/cm)	Permeability (mm/hr)	OM (%)	OC (%)	Total nitrogen (mg/kg)	Total phosphorus (mg/kg)	Potassium (mEq/L)	Calcium (mEq/L)	Sodium (mEq/L)
Organic fertilizers dependence	1											
Inorganic fertilizers dependence	-1.0000**	1										
pH	-0.4023	0.4023	1									
EC	0.7388*	-0.7388	-0.2210	1								
Permeability	-0.4161	0.4161	0.4675	-0.4296	1							
OM	0.7329*	-0.7329*	-0.1520	0.6971*	-0.5519	1						
OC	0.7329*	-0.7329*	-0.1520	0.6971*	-0.5519	1.0000**	1					
Total nitrogen	0.3524	-0.3524	0.0459	0.4819	0.3112	0.0590	0.0590	1				
Total phosphorus	-0.0221	0.0221	-0.2782	-0.2287	-0.4450	-0.2436	-0.2436	-0.5043	1			
Potassium	0.8121**	-0.8121**	-0.5656	0.6672*	-0.2313	0.5750	0.5750	0.3015	-0.2445	1		
Calcium	0.7391*	-0.7391*	0.0102	0.7182*	-0.3011	0.7398*	0.7398*	0.1167	-0.2681	0.5985	1	
Sodium	-0.1120	0.1120	0.8429**	0.1364	0.4948	0.0170	0.0170	0.2774	-0.4706	-0.1896	0.2855	1

*n= 10, r > 0.631897 significance level *P< 0.05, r > 0.764592 signifivance level **P< 0.01*

Fig. 5 Correlation matrix tree between Organic Fertilizer Dependence and soil properties in Baray Commune

The results of statistical analysis showed that there was no any trend detected between organic fertilizer dependence and soil properties in Samroang Commune, but in Baray Commune positive trend was detected between organic fertilizer dependence and soil properties. It can be disused that the trend in Samraong Commune was related to the percentage of organic fertilizer dependent, the duration of the application of organic material in farmland and the experience of farmers on farming practice. Similarly in Baray Commune, the relationship between organic fertilizer dependence and the soil properties showed a positive correlation. It can be disused that when farmer depended more on organic fertilizer input, it leads to increase in soil physical properties such organic matter and organic carbon and soil chemical properties including EC, K^+, Ca^{2+} and Na^+. It was discussed that the application of organic fertilizers can enhanced the accumulation of soil organic matter and organic carbon. According to Ebhin Masto et al., (2006), showed that increased in soil organic matter and soil organic carbon were considerably greater in soil receiving long-term used of farmyard manure, compost or straw along with inorganic fertilizers. More

importantly adding only inorganic fertilizers may results in deficiency of other nutrient and decline in soil physical and chemical properties as the trend was appeared in inorganic fertilizers dependence. Therefore, the trend become significantly when organic fertilizer has been applied for 10 years in Baray Commune.

CONCLUSION

The Organic Fertilizer Dependence was a main factor to the impact of soil properties such as soil physical and chemical properties. In Samraong Commune there was no trend appeared between Organic Fertilizer Dependence and soil properties, however in Baray Commune the trend were obvious when organic fertilizer has been applied. This change might related to the percentage of the organic fertilizers dependent, the long-term application of organic fertilizers as well as the experience and knowledge of farmers on farming practice. In addition, due to slowly decompose of organic fertilizers in the soil, it can be recommended that farmers have to apply more of organic material on their farmland. When organic fertilizers have been applied for many years the trend will show clearly on the effectiveness of organic fertilizer on soil properties.

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