Soil Physicochemical Status and Nutrient Management for Paddy Soils in the Lower Central Plain of Thailand after the Flood Disaster in 2011

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Abstract

The soil fertility status were evaluated for 29 paddy soils in Phra Nakhon, Si Ayutthaya and Pathum Thani provinces, Thailand that had been affected by the flood disaster in 2011. The chemical fertility status of the soils in the flood affected areas was medium, which is relatively superior to the pre-flood condition. The available potassium in most soils was slightly larger (mean = 220 mg kg^{-1}) than the values previously reported on these soils (mean = 188 mg kg^{-1}). However, mean values of available phosphorus for most soils were rather small (7.5 mg kg^{-1}), indicating a loss of phosphorus fertility and those farmers in the flood affected areas needed to apply additional phosphorus fertilizer in order to achieve satisfactory crop yields. Liming should also be used to minimize potential Al/metals toxicity and correct imbalances of plant nutrients. Several plant nutrients (NPK) and organic materials need to be regularly applied to maintain soil fertility levels at optimum values.

Key wards: Acid sulfate soils/ Soil fertility/ Soil quality/ Tropical soils

1. Introduction

In 2011, Thailand experienced the worst flood disaster in almost 70 years (Center for Climate Bureau of Meteorology, 2011). The main causes of the floods occurred mainly due to two reasons. First, continuous heavy rainfall throughout the rainy season along with the impact of monsoons and storms during January and October 2011. This resulted in the mean annual rainfall (1,973

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mm) being higher than in a normal year (average over 30 years = 1,539 mm) of approximately 300-500 mm (Department of Meteorology, 2011). Second, the speed of water drainage to the sea was slow, because the sea levels had risen higher than usual from 1.0 to 2.5 meters (Ministry of Agriculture and Cooperatives, 2012; Hydrographic Department Royal Thai Navy, 2012). Subsequently, residential, industrial, and agricultural areas were inundated. Agricultural areas suffered the most damage (Land Development Department, 2012). A total of 48 provinces were submerged, comprising a total area of around 13.7 Mha, of which 95% was cultivated with paddy rice (Office of Calamity and Agricultural Rick Prevention, 2011). Phra Nakhon Si Ayutthaya and Pathum Thani provinces are vital areas, which are used for paddy rice cultivation, this is then exported to several countries. However, these areas suffered the most damage by flooding with the water logging period being more than 30 days (Office of Calamity and Agricultural Rick Prevention, 2011). This flood phenomenon affected quality, price and trading of rice at both domestic and international levels. Furthermore, the flood damage, subsequently increased farmer's investment in crops and chemicals for plantation after the flood. In addition to the economic and social impacts, the flood also affected soil quality, which is a significant agricultural resource.

According to the information described above, the study on properties, nutrient status and fertility of soils in the areas affected by the flood in 2011 is considerably needed. Flood conditions for a sustained period may cause several changes in chemical properties (e.g., pH, OM, CEC and %BS) of soils. It may also affect availability of macro-micro nutrients (e.g., NPK) in soils, which are sensitive to the fertility level of the soils. The soil fertility is an important factor that governs plant growth and yield of agricultural crops. In order to achieve satisfactory crop yields, soil improvement is beneficial to agriculture in flood affected areas. Soil analysis helps to improve fertilizer efficiency and reduce the production costs to farmers. There are many related factors such as physical, chemical and mineralogical properties that control the availability of soil nutrients. Use of soil amendments to improve the properties of post-flooded soil and their fertility efficiency needs to be studied. This paper aims to provide information on soil properties and nutrient levels related to post-flood areas in 2011 of Phra Nakhon Si Ayutthaya and Pathum Thani provinces. The data presented here can be used to monitor and evaluate soil fertility, and their subsequent effects with fertilizer and soil amendment for sustainable soil management.

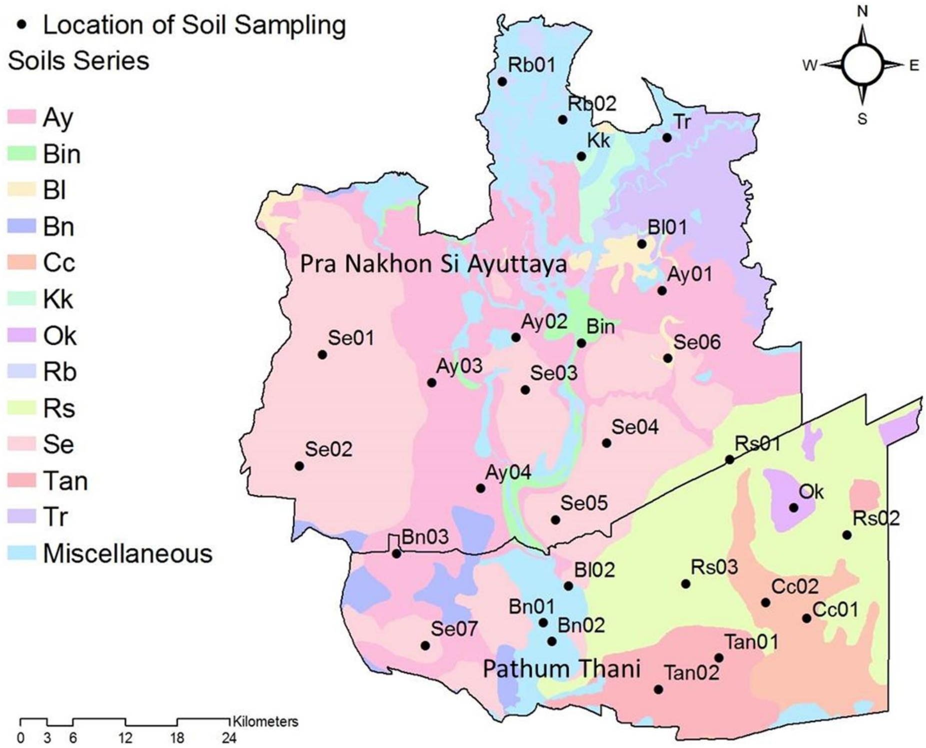

Figure 1: Soil series and sampling locations of flood affected soils in Phra Nakhon Si Ayutthaya and Pathum Thani provinces

2. Materials and Methodology

This study was carried out on the paddy soils in Phra Nakhon Si Ayutthaya and Pathum Thani provinces affected by the floods in 2011 (Figure 1). A total of 58 soil samples from 29 locations were obtained from surface (0-30 cm) and subsurface (30-60 cm) horizons by hand soil auger in March 2012. The soils consisted of 12 soil series, namely Ayutthaya Series (Ay01, Ay02, Ay03 and Ay04), Bang Pa-in Series (Bin), Bang Len Series (Bl01 and Bl02), Bang Khen Series (Bn01, Bn02, Bn03), Khok Krathiam Series (Kk), Chachoengsao Series (Cc01 and Cc02), Tha Rua Series (Tr), Ratchaburi Series (Rb01 and Rb02), Rangsit Series (Rs01, Rs02 and Rs03) and Sena Series (Se01, Se02, Se03, Se04, Se05, Se06 and Se07). Soil samples were gently crushed, mixed homogenously and sieved, by passing through a 2 mm sieve before physicochemical analysis according to standard procedures (National Soil Survey Center, 1996). Particle size distribution was analyzed by the pipette method (Day, 1965). Soil pH was determined in water using soil: liquid ratio of 1: 1. Organic carbon (OC) was determined by the Walkley and Black wet oxidation procedure (Walkley and Black, 1947) and for calculation of organic matter content (OM), the relationship OM = OC × 1.724 was used. Available phosphorus (P) was determined by the Bray II method (Bray and Kurtz, 1945). Available potassium (K) was determined by ammonium acetate extraction (1M NH_4OAc) at pH 7.0 (Thomas, 1982). Cation exchange capacity (CEC) was determined by saturating the exchange sites with 1M NH_4OAc at pH 7.0 (Chapman, 1965). Base saturation percentage by sum of cations is equal to the sum of bases extracted by NH_4OAc, divided by the CEC by sum of cations, and multiplied by 100 (Pratt, 1965). The concentrations of exchangeable cations (Ca, Mg, Na and K) were determined by an Atomic Absorption Spectrophotometry (AAS). Soil fertility status was evaluated using soil physiochemical properties according to standard criteria commonly used in Thailand (Office of Soil Resources Survey and Research, 1980).

In order to achieve an understanding of spatial distribution of soil fertility status in the flood affected areas, the geostatistical method, called kriging interpolation were used to produce the spatial distribution maps of soil attributes. This was used in evaluation of the soil fertility levels from the identified values to estimate the surrounding unidentified values in the entire studied area.

3. Results

3.1 Soil properties

Table 1 shows the physicochemical properties of soils affected by the flood disaster in 2011. The soil texture ranged from silt loam to clay. Soil pH in 1:1 water varied from ultra-acid to neutral (pH = 3.4-7.3), reflecting that some soils may contain certain sulfide materials, which are a common feature of acidic sulfate soils in the areas. Organic matter concentrations varied substantially from very low to very high (3.7-75 mg kg^{-1}) with the highest value found the surface horizon of Ay02 soil. This location is very close to a landfill site in Phra Nakhon Si Ayutthaya province. The ranges of available phosphorus were 3 to 23 mg kg^{-1}(very low to moderately high). Amounts of available K varied considerably from low to very high (53-2,411 mg kg^{-1}) with the highest value found in the surface horizon of Ay02 soil. Cation exchange capacity (CEC) values for the soils were mostly high (15-42 cmol kg^{-1}). Regarding the exchangeable bases, Ca was the main cation in the soils as compared with the other basic cations (Mg, Na, and K). Most of the soils (n = 20) clearly contained high concentrations of extractable Na with values ranging from high to very high (> 0.7 cmol kg^{-1}).

Figure 2 depicts the spatial distribution maps of soil chemical properties and concentrations of some plant nutrients in the flooded areas. Map implication, however, should be noted with caution as the number of sampling locations was rather low relative to the entire studied area, which only resulted in a moderate map description. For instance, the map for distribution of available K (Figure 2d) delineates high levels of this parameter for the entire area, albeit the observed values of these soils varied from low to very high (Table 1).

3.2 Fertility of the soils after the flood disaster in 2011

Based on the results are provided in Table 2, most of the soils had medium soil fertility level. This may indicate that the floods did not cause any adverse impacts on soil chemical properties even though the values of some soil properties in some locations were lower than those previously reported values (Udomsri S., and Hemsrichat P., 2003). The values of OM form this study (mean= 28 mg kg^{-1}) had a tendency to increase from the observed values before the flood in 2011 for all soils (mean= 19 mg kg^{-1}). Furthermore, concentrations of available K from this study (mean = 220 mg kg^{-1}) clearly increased in most of the soils, as compared with the values formerly reported (mean = 188 mg kg^{-1}) (Udomsri S., and Hemsrichat P., 2003; Thanachit et al., 2007). This may partly be attributed to the areas that have received recent sediment and organic material deposits from the floodwater, which is consistent with the result of Thanachit et al. (2007). The new sediments deposited on the surface soils may also be very thin, which is presumably incorporated into the top layer by tillage during soil preparation for rice cultivation. However, it should be noted that the variability of soil samplings that may cause deviation of the data should also be taken into consideration.

Table 1: Physicochemical property of paddy soils in Phra Nakhon Si Ayutthaya and Pathum Thani provinces after flooding in 2011

Soil Series[1/]	Depth (cm)	Texture[2/]	Sand	Silt	Clay	pH H_2O 1:1	OM $(g\ kg^{-1})$	Available P	Available K	CEC	Extractable K	Extractable Ca	Extractable Mg	Extractable Na
			(---------g kg^{-1}	---------)				(----mg kg^{-1}	----)	(---------------cmol kg^{-1}			-----------)	
Rb01	0-30	CL	27.9	42.9	29.2	5.3	25.2	15.0	53.4	16.2	0.14	5.8	2.4	0.37
	30-60	SiL	27.6	51.7	20.7	5.6	15.8	21.7	53.5	15.0	0.14	4.9	2.2	0.38
Rb02	0-30	SiL	9.8	49.9	40.3	5.5	6.1	10.3	97.8	21.2	0.25	8.9	3.0	0.57
	30-60	SiCL	11.6	49.7	38.7	6.2	3.7	3.0	59.3	18.8	0.15	7.8	3.7	0.91
Kk	0-30	SiC	3.3	42.4	54.3	5.7	32.9	10.5	153.2	31.2	0.39	14.2	4.7	0.67
	30-60	C	2.1	38.0	59.9	5.7	14.8	5.7	143.5	29.4	0.37	12.4	4.5	0.85
Tr	0-30	SiCL	19.1	50.1	30.7	6.8	10.9	18.4	99.7	26.2	0.26	8.7	5.2	0.84
	30-60	SiCL	15.3	51.2	33.6	7.0	7.9	11.7	165.4	27.5	0.42	12.7	6.3	0.74
Bl01	0-30	HC	3.6	35.7	60.7	6.3	38.3	2.5	120.6	42.5	0.31	20.2	6.4	0.82
	30-60	HC	1.6	25.3	73.1	6.1	22.1	3.3	112.6	43.1	0.29	20.0	6.5	1.06
Ay01	0-30	C	3.7	38.8	57.5	5.8	41.0	4.8	106.3	31.2	0.27	13.7	5.0	1.57
	30-60	HC	2.1	37.9	60.0	5.3	16.2	1.3	79.7	30.0	0.20	13.0	5.4	1.75
Se01	0-30	SiC	6.1	40.8	53.0	4.5	46.4	8.9	175.0	28.7	0.45	7.0	3.0	0.60
	30-60	SiC	3.7	48.0	48.3	3.8	24.2	1.6	166.4	26.2	0.43	5.4	2.5	0.74
Se02	0-30	SiC	5.7	47.2	47.1	3.7	29.7	4.0	158.8	26.2	0.41	8.3	4.0	0.98
	30-60	SiC	6.3	44.1	49.6	3.7	11.9	1.9	134.1	23.7	0.34	6.9	4.0	1.18
Ay02	0-30	SiCL	6.5	55.2	38.3	6.2	75.3	14.3	2411	33.1	6.18	11.5	4.9	2.55
	30-60	HC	2.8	36.2	61.0	6.5	27.8	9.4	1252	29.4	3.21	11.1	4.5	2.41
Ay03	0-30	SiC	4.6	47.8	47.6	3.6	36.0	9.5	315.4	33.1	0.81	7.5	5.9	1.60
	30-60	C	3.3	39.5	57.1	3.7	18.3	0.1	146.6	24.4	0.38	10.2	8.1	1.82
Bin	0-30	HC	2.9	31.1	65.9	5.9	29.5	6.1	194.5	38.7	0.50	14.5	4.7	1.65
	30-60	SiC	3.7	44.3	51.9	5.0	12.7	4.1	120.3	32.5	0.31	13.4	5.0	1.41
Se03	0-30	C	6.4	38.8	54.8	5.3	45.4	17.9	125.9	29.4	0.32	8.6	4.5	1.10
	30-60	SiC	7.8	43.1	49.2	3.5	15.8	4.1	94.5	26.9	0.24	8.3	3.2	1.06
Se04	0-30	C	4.2	38.8	57.1	4.1	34.2	2.1	192.9	29.4	0.49	9.1	4.9	1.36
	30-60	SiC	1.8	43.0	55.2	3.8	19.3	1.7	233.7	29.4	0.60	7.4	4.4	0.71
Se05	0-30	SiC	4.8	40.6	54.6	4.6	56.4	5.3	188.1	33.7	0.48	9.5	4.6	1.46
	30-60	HC	3.0	37.0	60.0	4.1	22.1	1.5	159.4	21.9	0.41	8.5	5.3	0.99
Rs01	0-30	C	10.6	34.6	54.7	5.3	59.3	5.9	128.8	32.5	0.33	11.9	4.7	1.14
	30-60	C	4.9	37.9	57.2	4.3	40.5	2.5	102.9	29.4	0.26	9.5	5.6	0.70
Se06	0-30	C	9.2	37.1	53.7	3.6	35.1	7.7	266.5	28.1	0.68	9.4	3.5	1.58
	30-60	C	6.9	35.1	58.0	3.5	13.6	1.6	151.3	24.4	0.39	5.3	2.5	1.11
Ay04	0-30	SiC	6.4	44.2	49.4	5.0	47.7	22.9	104.1	26.2	0.27	11.3	6.4	1.09
	30-60	SiC	6.3	43.0	50.7	4.8	15.3	1.9	76.8	16.2	0.20	9.7	4.8	1.12
Rs02	0-30	SiC	2.4	46.9	50.7	4.1	37.7	16.9	190.2	27.5	0.49	5.3	3.1	0.91
	30-60	SiC	3.4	43.1	53.5	3.8	29.5	22.0	142.6	25.6	0.37	4.2	3.0	0.56
Cc01	0-30	C	2.2	39.8	58.0	5.4	52.3	2.8	230.9	34.3	0.59	10.3	10.2	1.66
	30-60	HC	1.6	36.5	61.9	4.8	31.8	2.4	201.5	40.0	0.52	8.4	11.4	1.48
Cc02	0-30	SiC	2.6	40.7	56.7	5.4	33.1	9.9	251.9	35.6	0.65	8.7	8.8	1.51
	30-60	HC	1.2	32.8	66.0	5.2	19.4	5.1	236.1	28.7	0.61	6.8	12.0	1.37
Tan01	0-30	SiC	2.1	41.6	56.3	4.9	31.0	13.5	258.7	27.5	0.66	10.1	6.6	1.63
	30-60	SiC	4.5	43.7	51.7	3.9	18.0	7.4	183.7	23.7	0.47	4.7	6.1	1.25
Tan02	0-30	SiC	4.3	46.9	48.8	4.7	51.2	8.7	249.3	23.7	0.64	8.9	4.2	1.24
	30-60	SiC	6.6	45.6	47.9	3.8	26.0	3.0	210.7	21.9	0.54	5.2	4.1	1.01
Rs03	0-30	SiC	10.7	44.6	44.7	6.8	18.2	12.4	257.9	20.6	0.66	16.3	4.5	0.82
	30-60	SiC	8.7	41.8	49.5	6.9	15.2	7.3	404.0	25.0	1.04	18.9	5.2	1.17
Ok	0-30	C	4.9	38.7	56.4	3.9	22.2	12.8	383.8	24.4	0.98	4.3	4.1	1.16
	30-60	C	7.3	37.8	54.9	4.3	15.2	0.6	302.2	25.0	0.77	4.7	4.6	0.84
Bl02	0-30	SiC	8.0	46.3	45.7	5.9	30.5	4.5	101.2	22.5	0.26	10.4	4.2	0.84
	30-60	SiCL	14.8	47.0	38.2	6.3	10.6	3.4	57.6	19.4	0.15	8.2	4.2	0.75
Bn01	0-30	SiC	4.9	50.9	44.2	5.0	59.3	10.6	119.3	21.9	0.31	10.7	3.6	0.84
	30-60	SiC	3.1	44.1	52.8	5.0	20.4	7.2	83.3	25.0	0.21	9.8	4.5	0.98
Bn02	0-30	SiC	4.5	51.0	44.5	5.4	41.7	5.2	157.8	23.7	0.40	9.9	4.4	1.73
	30-60	SiC	1.6	52.0	46.4	4.7	8.7	1.0	81.8	20.0	0.21	7.9	4.0	0.83
Bn03	0-30	SiC	4.0	51.7	44.4	5.4	33.9	22.7	120.9	22.5	0.31	10.1	4.9	1.30
	30-60	SiC	3.3	45.6	51.1	4.4	16.3	3.3	90.3	20.6	0.23	14.6	2.9	0.74
Se07	0-30	SiC	3.3	45.7	50.9	5.6	40.8	7.5	174.4	26.2	0.45	9.8	5.1	1.18
	30-60	SiC	2.0	43.8	54.2	4.4	12.2	2.1	139.2	23.1	0.36	5.7	4.5	1.40
Mean±SD			6.2±5.4	43±5.9	51±9.2	5.0±1.0	28±15	7.5±6.1	220±332	27±6.0	0.56±0.85	9.7±3.7	4.9±1.9	1.1±0.44

[1/] Rb = Ratchaburi, Kk = Khonk Krathiam, Tr = Tha Rua, Bl = Bang Len, Ay = Ayutthaya, Se = Sena, Bin = Bang Pa-in, Rs = Rangsit, Cc = Chachoengsao, Tan = Thanyaburi, Ok = Ongkharak, Bn = Bang Khen

[2/] Textural class; C = clay, CL = clay loam, HC = heavy clay, SiL = silt loam, SiC = silt clay SiCL = silty clay Loam

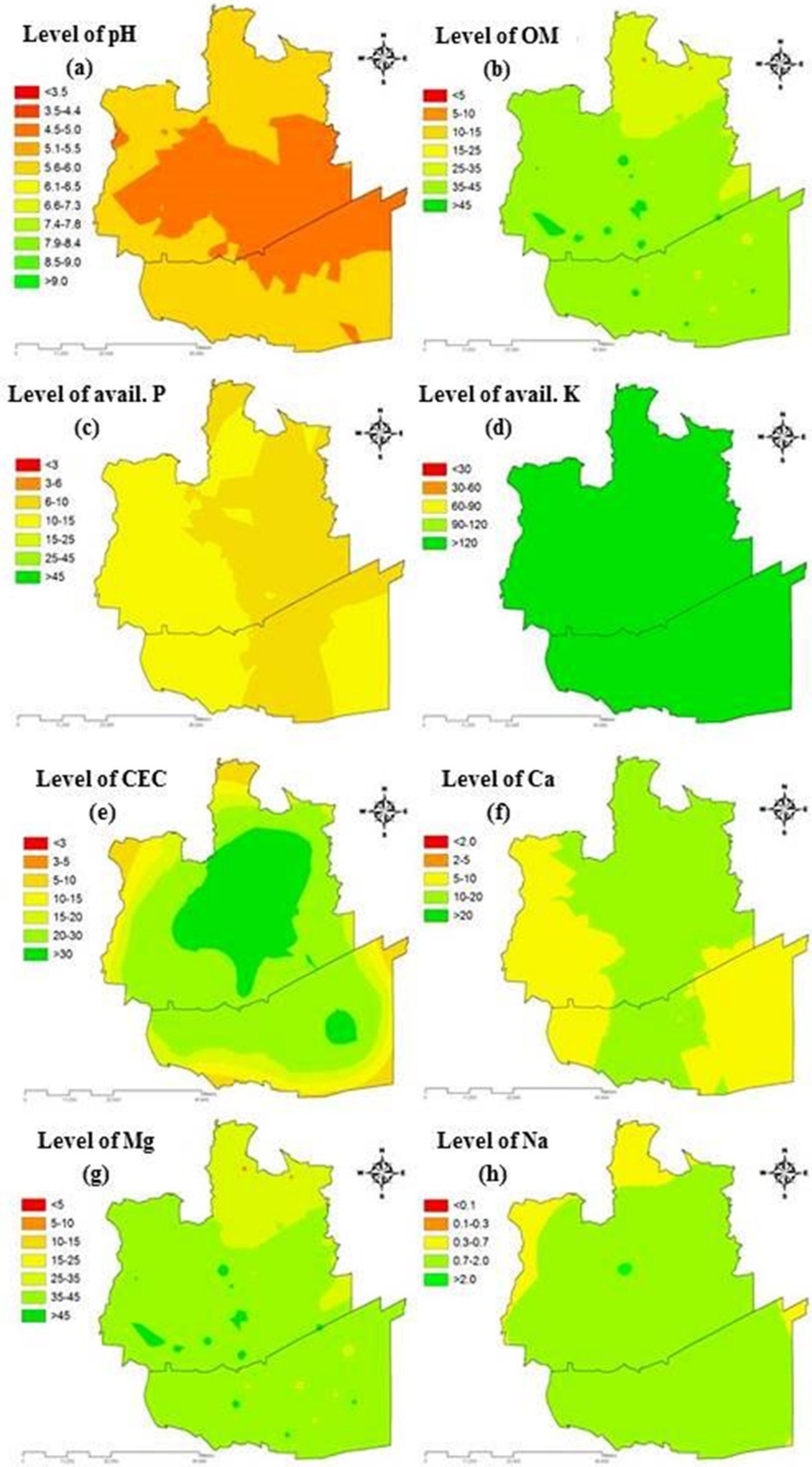

Figure 2: Spatial distribution maps of some chemical properties in the floods areas in Phra Nakhon Si Ayutthaya and Pathum Thani provinces: (a) pH, (b) OM, (c) available P, (d) available K (e) CEC, and (f, g, h) extractable Ca, Mg and Na, respectively

Table 2: Soil fertility evaluation and levels of some chemical properties of soils affected by flooding, according to standard criteria used in Thailand (Office of Soil Resources Survey and Research, 1980).

Soil Series	Depth cm	OM Level1/	Level of Available1/ P	K	CEC Level1/	Level of Extractable1/ Ca	Mg	Na	Fertility Score2/	Fertility status3/
Rb01	0-30	MH	M	L	MH	M	M	M	9	M
	30-60	M	MH	L	M	L	M	M	10	M
Rb02	0-30	L	M	H	H	M	H	M	11	M
	30-60	VL	VL	L	MH	M	H	H	7	L
Kk	0-30	MH	M	VH	VH	H	H	M	12	M
	30-60	ML	L	VH	H	H	H	H	10	M
Tr	0-30	ML	MH	H	H	M	H	H	11	M
	30-60	L	M	VH	H	H	H	H	11	M
Bl01	0-30	H	VL	VH	VH	VH	H	H	12	M
	30-60	M	L	H	VH	H	H	H	11	M
Ay01	0-30	H	L	H	VH	H	H	H	12	M
	30-60	M	VL	M	H	H	H	H	10	M
Se01	0-30	VH	ML	VH	H	M	M	M	12	M
	30-60	M	VL	VH	H	M	M	H	10	M
Se02	0-30	MH	L	VH	H	M	H	H	11	M
	30-60	ML	VL	VH	H	M	H	H	10	M
Ay02	0-30	VH	M	VH	VH	H	H	VH	1[4]	H
	30-60	MH	ML	VH	H	H	H	VH	11	M
Ay03	0-30	H	ML	VH	VH	M	H	H	12	M
	30-60	M	VL	VH	H	H	VH	H	12	M
Bin	0-30	MH	L	VH	VH	H	H	H	11	M
	30-60	ML	L	VH	VH	H	H	H	10	M
Se03	0-30	VH	MH	VH	H	M	H	H	13	H
	30-60	M	L	H	H	M	H	H	11	M
Se04	0-30	MH	VL	VH	H	M	H	H	11	M
	30-60	M	VL	VH	H	M	H	H	11	M
Se05	0-30	VH	L	VH	VH	M	H	H	12	M
	30-60	M	VL	VH	H	M	H	H	11	M
Rs01	0-30	VH	L	VH	VH	H	H	H	12	M
	30-60	H	VL	H	H	M	H	M	12	M
Se06	0-30	H	ML	VH	H	M	H	H	12	M
	30-60	ML	VL	VH	H	M	M	H	10	M
Ay04	0-30	VH	MH	H	H	H	H	H	14	H
	30-60	M	VL	M	MH	M	H	H	10	M
Rs02	0-30	H	MH	VH	H	M	H	H	13	H
	30-60	MH	MH	VH	H	L	M	M	12	M
Cc01	0-30	VH	VL	VH	VH	H	VH	H	12	M
	30-60	MH	VL	VH	VH	M	VH	H	11	M
Cc02	0-30	MH	ML	VH	VH	M	VH	H	11	M
	30-60	M	L	VH	H	M	VH	H	11	M
Tan01	0-30	MH	M	VH	H	H	H	H	12	M
	30-60	M	ML	VH	H	L	H	H	11	M
Tan02	0-30	VH	ML	VH	H	M	H	H	12	M
	30-60	MH	VL	VH	H	M	H	H	11	M
Rs03	0-30	M	M	VH	H	H	H	H	13	H
	30-60	M	ML	VH	H	H	H	H	12	M
Ok	0-30	MH	ML	VH	H	L	H	H	12	M
	30-60	M	VL	VH	H	L	H	H	11	M
Bl02	0-30	MH	L	H	H	H	H	H	11	M
	30-60	ML	L	L	MH	M	H	H	7	H
Bn01	0-30	VH	M	H	H	H	H	H	13	H
	30-60	M	ML	M	H	M	H	H	10	M
Bn02	0-30	H	L	VH	H	M	H	H	12	M
	30-60	L	VL	M	MH	M	H	H	8	M
Bn03	0-30	MH	MH	VH	H	H	H	H	13	H
	30-60	M	L	H	H	H	M	H	12	M
Se07	0-30	H	ML	VH	H	M	H	H	12	M
	30-60	ML	VL	VH	H	M	H	H	10	M

1/ VL = very low, L = low, ML = moderately low, M = medium, MH = moderately high, H = high, VH = very high
2/ Fertility score: <7 = L, rage 8-12 = M, >13 = H
3/ Fertility status: L = low level, M = moderate level, H = high level

4. Discussions

Overall results indicated that most surface soils (0-30 cm) in the flood affected areas used for irrigated rice production had relatively high values of OM, CEC, available K and exchangeable cations. However, available phosphorus for these soils was somewhat poor (mean = 7.5 mg kg^{-1}). Therefore, farmers in flooded areas should be strongly advised to increase rates of phosphorus fertilizer more than the usual rate of fertilization. Nevertheless, phosphorus fertilizer should not be applied every season as there is always some residual effects in paddy fields. Moreover, liming should also be applied in some soils to increase the value of pH (pH 5.5-6.5) to optimize plant growth, and amend nutrient imbalances as well as correction of Al/trace element toxicity induced from strong acidity of the soils (pH 3-4). In addition, fertilization and organic matter management are normally required to enhance and sustain the fertility and quality of these soils.

5. Conclusions

This study showed that the fertility level of soils after the floods in 2011 had medium soil fertility level. We postulate that the flood did not have a big effect on soil chemical properties. Soil fertility indicators determined in this study showed that OM and K at surface layers of soils were higher than several previous studies. This could be a consequence of newly supplied sediments carried by the flood in 2011 and deposited in those particular areas. However, major plant nutrients particularly P was relatively low. It is an expected condition because P in soil is mainly supplied by chemical fertilizers. Therefore, it is suggested that farmers in the flood affected area should utilize more P fertilizer than normally recommended rates in order to satisfy the nutrient requirements for plant growth. The values of soil fertility conditions in the flood affected areas in this study can provide a baseline data for further monitoring of soil quality status in these areas.

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