Spatial Distribution of Potentially Toxic Trace Elements of Agricultural Soils in the Lower Central Plain of Thailand after the 2011 Flood

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Abstract

A study has been carried out on 29 locations of paddy soils in the lower Central Plain in Phra Nakhon Si Ayutthaya and Pathum Thani provinces, Thailand, to identify geochemical distribution of major and potentially toxic trace elements and to determine their baseline concentrations in the soils. The geostatistical technique was also employed to generate spatial distribution maps of toxic elements in the area. Results of the study clearly indicated that total concentrations of toxic elements in both surface and subsurface soils did not exceed the soil quality standard limit for habitat and agriculture according to the Pollution Control Department (PCD) of Thailand. The concentrations of several heavy metals in many soils, located in the proximity of the main industrial estates in the areas were rather similar to those of other locations; except for Ay02 site which is located adjacent to a landfill, and had high concentrations of Cr, Cu, Ni, Pb and Zn. Factor analysis indicated that the chemical composition in the soils were rather diffused. Three distinct element affinity groups were recognized: the pH group, the clay group and the sand group. The spatial distribution maps of potentially toxic trace elements unraveled a large variation among elements and locations.

Key words: Multivariate analysis/ Factor analysis/ Kriging/ Soil pollution/ Micronutrients

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1. Introduction

Contamination of heavy metals in soil is a global concern because they are highly resistant to degradation in terrestrial environments (Adriano, 2001). Sources of heavy metals can be derived from both natural origins (weathering of parent rocks), and from anthropogenic activities including agricultural use, such as the application of fertilizers and pesticides, and various types of industrial activities such as mining, smelting and fuel combustion (Rajapaksha, 2012; Vassilev, 2004). These activities can affect the biogeochemical cycling of elements, which may cause pollution of heavy metals in soils and the environment; These may lead to biomagnification in the food chains and in turn have an adverse effect on humans and other living things (Kabata–Pendias, 2004). Many heavy metals such as Cu, Mn, Zn and Ni are considered essential plant micronutrients if they are present at low concentrations. However, at very high concentrations, these trace elements can pollute the soils and can have an acute or chronic effect on human health. The Pollution Control Department (PCD) of Thailand designates the critical values for soil contamination of heavy metals suitable for a human environment and agriculture as follows: 1,800 mg/kg for Mn and 1,600 mg/kg for Ni (Pollution Control Department, 2004). These metals are also in the list of important pollutants of US Environmental Protection Agency (US–EPA).

The flood in 2011 was a severe flood event that occurred from July 25, 2011 to January 16, 2012. This flood damage affected 65 provinces (PRD, 2012). It heavily damaged the agricultural, industry, economy and society especially in the lower central plain, which is an important agricultural and industrial area of Thailand. About 2.22 million hectares of Pra Nakhon Si Ayutthaya province agricultural areas were affected (LDD, 2012). Seven industrial estates in Pra Nakhon Si Ayutthaya and Pathum Thani provinces were also damaged. Industrial estates are sources of many chemicals including toxic trace elements such as Cd, Pb, Hg, Ni and Cr. The spread of water from these industrial areas during the flood may have caused possible accumulation of toxic trace elements in soils of the surrounding areas.

Therefore, the main objectives of this study were to quantify the total concentrations of heavy metals and essential trace elements of paddy soils in Phra Nakhon Si Ayutthaya and Pathum

Thani provinces, which are two of the main areas for agriculture and industry using multivariate analysis, and to provide distribution maps of toxic elements in the soils in order to obtain information for managing these agricultural land areas in the future.

2. Methodology

Eighty–seven soil samples from 12 soil series in paddy fields in Phra Nakhon Si Ayutthaya and Pathum Thani provinces covering an area of 4,082 km^2 were collected in February 2013 for this study (Figure 1). The soil samples consisted of Inceptisols (Ay, Bin, Bn, Cc, Ok, Rb, Rs, Se, Tan and Tr), Vertisols (Kk) and Mollisols (Bl). The soil sampling criteria was based on the basis of soil series, land uses and flood affected areas in 2011.

The surface (0–30 cm) and subsurface soils (30–60 and 60–100 cm) were collected and stored in plastic bags. The soil samples were air–dried, gently crushed and passed through a 2 mm silver sieve before analysis. Physicochemical properties were determined by standard procedures (Soil Survey Staff, 2009).Particle size distribution was determined by the pipette method. Various soil pH values were measured by using ratios of 1:1 (w/v), 1:1 (w/v) and 1:50 (w/v) for soil: water, soil: KCl, and soil: NaF, respectively. Organic matter (OM) content was quantified with the Walkey–Black titration method. Cation exchange capacity (CEC) of soil was determined using 1M NH_4OAc at pH 7.0. The chemical composition of soils was measured by a combination of an aqua regia digestion (HCl and HNO_3) followed by Microwave Plasma–Atomic Emission Spectrometer (MP–AES) and Atomic Absorption Spectrophotometer (AAS). Aluminum, Si, Fe, Mg, Mn, Cd, Cr, Cu, As, Hg, Se, Mo, V and Zn in the aqua regia digests were determined using an Agilent 4100 MP-AES, whereas Ni, Co and Pb were determined using a Varian AA 240 Atomic Absorption Spectrometers. The accuracy of the elemental concentrations was checked using a standard reference material (STSD–3).

The kriging interpolation technique was used to generate the spatial distribution of heavy metals in the study area. This geostatistical technique allows us to consider the distance and the degree of variation between the recognized data points (heavy metal concentration) and estimating values in unknown areas (Figure 2).

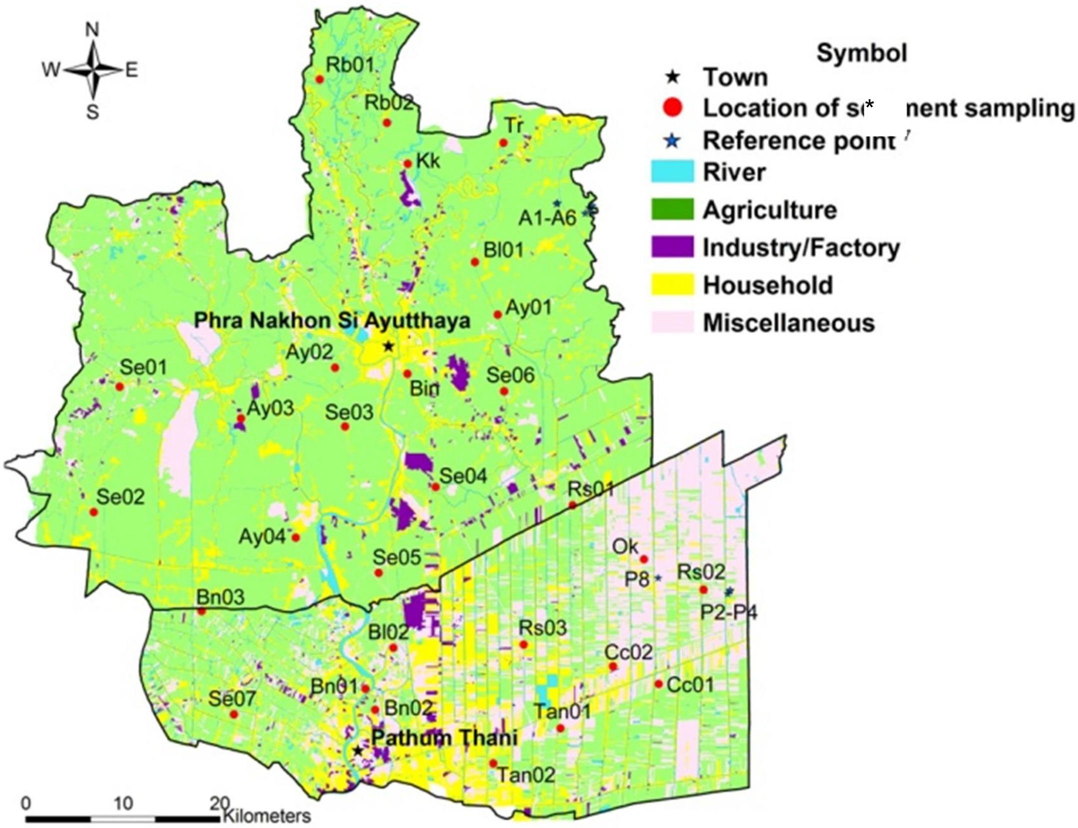

Figure 1: Soil sampling locations with land uses in Phra Nakhon Si Ayutthaya and Pathum Thani provinces

*Reference locations obtained from Land Development Department (2008).

3. Results

The range, mean and standard deviation for physicochemical properties of the studied samples are given in Table 1. The soil texture varied from silt loam to clay, but most soils had clayey texture throughout the soil depth. The values of pH in water varied substantially from very acid to slightly alkaline. The pH in KCl solution for all soils was lower than their pH in water, indicating that negative surface charge prevails. The pH in NaF being an indication of the rather high amounts of the OH group, reflecting that the soils had relatively high reactive surface for adsorbing ions. The extents of OM and CEC showed similar trend.

The total concentrations of elemental composition of soils in the surface and subsurface soils are provided in Table 2 and 3. Aluminum, Fe and Mg were major elements found in all soils both in the surface and subsurface soils. Silicon and Mn were present in minor concentrations. Cobalt, Cr, Cu, Mo, Ni, Pb, V and Zinc occurred in smaller extents. Highly toxic elements such as As and Hg were not detected in any sample. However, Cd was observed only in the subsurface soils of Rs01, Se01 and Se06 locations. Selenium was also undetectable. Nonetheless, the concentrations of toxic elements (Cd, Cr, Pb, Mn, Ni and Se) in both surface and subsurface soils did not exceed the soil quality standard for habitat and agriculture according to Pollution Control Department (PCD) of Thailand (Tables 2 and 3).

We also compared our data with the data obtained from Land Development Department (LDD) in 2008 for Phra Nakhon Si Ayutthaya and Pathum Thani provinces. The concentrations of Cu (23 mg/kg), Pb (15 mg/kg) and Zn (47 mg/kg) in the Tr soil which is close to the LDD sampling site in 2008, were slightly higher than the values observed by LDD (Cu = 16, Pb = 6 and Zn = 24 mg/kg). However, the concentration of As decreased from 3.4 mg/kg to undetectable level. For Rs02 and Ok soils located in Pathum Thani province, the Pb concentrations ranged from 30–31 mg/kg, which were larger than those values observed by LDD (Pb = 16–18 mg/kg). Arsenic, Cd and Cu concentrations were slightly lower than those observed by LDD in 2008. However, comparing the data of this study to the published data should be treated with caution due to the spatial variability of sampling locations.

The multivariate analysis of standardized raw data for element concentrations and other relevant properties revealed that the first and second factors represented only 49% of variation in the data for these soils (Figure 3). From the variable diagram, the elements and the associated soil properties can be mainly separated into 3 groups of similar geochemical behavior (Figure 3a). The first group (#1) was pH group including field pH, pH H_2O, pH KCl, pH NaF, Mn, Ni, Zn, Co and Mg. The second group (#2) was clay group including clay, CEC, Al, Cu, Cr and V. The third group (#3) was sand group including Si, sand and silt.

Table 1: Range, mean and standard deviation for physicochemical properties of Thai paddy soils in Phra Nakhon Si Ayutthaya and Pathum Thani provinces

Properties	Total		Topsoil		Subsoil	
	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
All sample (n=87)						
pH (field)	3.0–8.0	5.9±1.1	4.0–8.0	6.4±0.82	3.0–7.5	5.7±1.2
pH (H_2O)	3.0–7.3	4.9±1.1	3.6–6.8	5.2±0.88	3.0–7.3	4.7±1.1
pH (KCl)	2.6–6.4	4.1±1.0	3.1–6.4	4.5±0.84	2.6–6.4	4.0±1.1
pH (NaF)	8.4–10	10±0.4	9.1–10	9.5±0.28	8.4–10	9.6±0.39
OM (g/kg)	3.1–75	22±16	6.1–75	38±15	3.1–50	14±9.2
CEC ($cmol_+$/kg)	8.8–43	26±6.3	16–42	28±5.8	8.8–43	25±6.2
Sand (%)	1.2–28	6.3±5.5	2.1–28	6.5±5.4	1.2–28	6.2±5.5
Silt (%)	25–59	43±6.0	31–55	43±5.8	25–59	42±6.1
Clay (%)	21–73	51±9.3	29–66	50±8.4	21–73	52±10
Ayutthaya (n=51)						
pH (field)	3.5–8.0	6.2±1.1	5.5–8.0	6.6±0.72	3.5–7.0	6.0±1.1
pH (H_2O)	3.2–7.3	4.9±1.1	3.6–6.8	5.1±1.0	3.2–7.3	4.8±1.2
pH (KCl)	2.8–6.1	4.2±1.0	3.1–5.7	4.4±0.86	2.8–6.1	4.0±1.1
pH (NaF)	8.8–10	9.6±0.33	9.1–10	9.5±0.27	8.8–10	9.6±0.35
OM (g/kg)	3.7–75	22±16	6.1–42	38±17	3.7–40	14±7.8
CEC ($cmol_+$/kg)	16–43	28±5.8	16–42	30±6.1	8.8–43	25±7.2
Sand (%)	2.1–28	7.5±6.5	3.9–27.9	7.9±6.5	1.2–28	7.3±6.6
Silt (%)	31–55	43±5.8	31–55	42±6.3	25–59	42±6.2
Clay (%)	29–66	50±8.4	29–66	50±10	21–73	51±11
Pathumthani (n=36)						
pH (field)	3.0–7.5	5.6±1.0	4.0–7.0	6.1±0.87	3.0–7.5	5.3±1.0
pH (H_2O)	3.0–6.9	4.8±0.99	3.9–6.8	5.2±0.77	3.0–6.9	4.7±1.1
pH (KCl)	2.6–6.4	4.1±1.0	3.2–6.4	4.5±0.84	2.6–6.4	3.9±1.0
pH (NaF)	8.4–10	9.5±0.38	9.2–10.3	9.5±0.31	8.4–10	9.5±0.41
OM (g/kg)	3.1–59	22±16	18–59	37±12	3.1–50	15±11
CEC ($cmol_+$/kg)	17–40	25±4.6	21–36	26±4.8	17–40	24±4.5
Sand (%)	1.2–15	4.6±2.9	2.1–11	4.5±2.6	1.2–15	4.7±3.1
Silt (%)	33–55	43±5.7	39–52	45±4.5	33–55	42±6.1
Clay (%)	38–66	52±6.9	44–58	50±5.5	38–66	53±7.4

Table 2: Concentrations of major and trace elements in surface soil samples (0–20 cm) from paddy soils in Phra Nakhon Si Ayutthaya and Pathum Thani provinces

Location	Al	Si	Fe	Mg	Mn	Cd	Co	Cr	Cu	As	Hg	Se	Mo	Ni	Pb	V	Zn
	(——g/kg				——)	(——mg/kg											——)
Ayutthaya																	
Ay01	37	0.09	33	2.0	0.11	nd	15	74	38	nd	nd	nd	nd	18	24	134	35
Ay02	38	nd	26	2.2	0.27	nd	17	94	52	nd	nd	nd	nd	27	41	102	84
Ay03	34	0.25	31	2.8	0.34	nd	19	66	23	nd	nd	nd	25	21	32	61	57
Ay04	20	0.64	17	1.4	0.10	nd	10	44	21	nd	nd	nd	11	17	31	46	38
Bin	38	0.021	33	2.8	0.51	nd	18	60	29	nd	nd	nd	5.5	20	24	91	51
Bl01	67	0.47	42	4.0	0.30	nd	15	86	45	nd	nd	nd	nd	21	23	164	47
Kk	36	1.15	26	2.5	0.25	nd	13	66	31	nd	nd	nd	1.9	19	24	96	46
Rb01	22	0.72	27	2.2	0.36	nd	15	55	20	nd	nd	nd	5.0	21	22	58	53
Rb02	23	1.21	31	2.5	0.41	nd	17	56	20	nd	nd	nd	0.94	20	26	56	44
Rs01	34	0.28	19	1.4	0.12	nd	10	59	26	nd	nd	nd	8.9	19	17	69	31
Se01	25	nd	12	1.0	0.049	nd	6.6	47	22	nd	nd	nd	13	16	28	54	27
Se02	31	0.007	23	1.5	0.045	nd	7.1	72	25	nd	nd	nd	9.0	12	43	71	23
Se03	29	0.44	14	1.3	0.075	nd	6.8	53	25	nd	nd	nd	14	14	32	79	30
Se04	27	0.21	22	1.3	0.060	nd	8.5	46	20	nd	nd	nd	13	13	26	58	26
Se05	34	0.32	20	1.5	0.094	nd	8.6	59	25	nd	nd	nd	8.6	19	30	67	43
Se06	26	0.55	43	1.3	0.089	nd	9.6	60	23	nd	nd	nd	nd	14	25	103	24
Tr	30	0.37	32	2.9	0.62	nd	19	61	23	nd	nd	nd	nd	20	15	79	47
Pathumthani																	
Bl02	28	0.33	34	3.2	0.92	nd	21	64	25	nd	nd	nd	nd	26	30	69	59
Bn01	21	0.32	22	1.7	0.16	nd	14	54	27	nd	nd	nd	21	18	25	61	55
Bn02	19	0.48	15	1.5	0.098	nd	8.4	42	21	nd	nd	nd	11	14	26	47	45
Bn03	23	1.49	11	1.3	0.11	nd	9.1	46	20	nd	nd	nd	14	20	22	37	38
Cc01	19	1.32	21	2.3	0.15	nd	16	49	20	nd	nd	nd	5.4	20	37	40	40
Cc02	26	0.47	17	2.4	0.19	nd	10	49	19	nd	nd	nd	12	15	27	38	26
Ok	28	0.49	41	1.6	0.049	nd	6.6	66	25	nd	nd	nd	nd	10	31	85	20
Rs02	19	0.48	15	1.5	0.098	nd	6.3	48	20	nd	nd	nd	8.5	10	30	60	19
Rs03	24	0.35	30	1.8	0.10	nd	8.4	57	24	nd	nd	nd	nd	12	26	60	28
Se07	30	0.38	18	1.9	0.12	nd	6.9	59	23	nd	nd	nd	11	14	25	52	36
Tan01	26	0.51	15	1.9	0.088	nd	7.9	59	22	nd	nd	nd	14	14	33	53	24
Tan02	21	0.77	18	1.2	0.069	nd	6.9	49	20	nd	nd	nd	18	13	30	50	21
All sample	29±9	0.5±0.4	25±9	2±0.7	0.2±0.2	nd	12±5	59±12	25±8	nd	nd	nd	8±7	17±4	28±6	70±29	39±15
Ayutthaya	32±11	0.4±0.4	27±9	2±0.8	0.2±0.2	nd	13±5	62±13	28±9	nd	nd	nd	7±7	18±4	27±7	82±31	42±15
Pathumthani	24±4	0.6±0.4	22±9	2±0.6	0.2±0.2	nd	10±5	53±8	22±3	nd	nd	nd	10±7	16±5	29±4	54±14	34±14
STSD–3 (n=4)	17±0.8	0.9±0.3	39±2	8±0.3	3±0.1	0.4±0.1	17±2	51±3	33±0.9	nd	nd	nd	28±0.6	25±3	36±8	85±7	173±6
Recommended Values [A]			34			1	14	34	38				7	25	39	61	192
Critical soil concentration [B]					<1.8	<37		<300		<3.9	<23	<390		<1,600	<400		

nd = non detectable.

[A] Recommended values of STSD–3 for partial extraction elements by HNO_3 – HCl. (CANMET Mining and Mineral Sciences Laboratories, 2011)

[B] Critical soil concentrations of heavy metals for habitat and agricultural use, Pollution Control Department of Thailand (Pollution Control Department, 2004).

Table 3: Concentrations of major and trace elements in subsurface* soils from paddy soils in Phra Nakhon Si Ayutthaya and Pathum Thani provinces

Location	Al	Si	Fe	Mg	Mn	Cd	Co	Cr	Cu	As	Hg	Se	Mo	Ni	Pb	V	Zn
	(g/kg				)	(mg/kg											)
Ayutthaya																	
Ay01	38	0.06	30	1.8	0.059	nd	15	73	38	nd	nd	nd	4.0	15	26	130	23
Ay02	37	0.21	29	2.0	0.45	nd	16	79	37	nd	nd	nd	nd	26	39	99	57
Ay03	35	0.18	25	2.5	0.46	nd	15	63	23	nd	nd	nd	4.6	24	33	63	50
Ay04	29	0.17	35	1.7	0.084	nd	10	61	18	nd	nd	nd	2.3	15	33	54	40
Bin	37	0.26	35	2.0	0.34	nd	8.8	72	30	nd	nd	nd	0.82	18	28	115	38
Bl01	52	0.25	31	3.1	0.21	nd	15	95	49	nd	nd	nd	nd	23	24	178	48
Kk	39	0.61	27	2.5	0.39	nd	14	74	31	nd	nd	nd	1.4	21	24	112	40
Rb01	25	1.05	31	2.5	0.45	nd	17	59	20	nd	nd	nd	1.2	22	25	61	49
Rb02	28	0.90	33	2.9	0.74	nd	21	67	24	nd	nd	nd	nd	23	26	71	54
Rs01	30	0.44	42	1.4	0.047	0.30	8.6	65	23	nd	nd	nd	6.2	15	32	99	26
Se01	24	0.19	22	1.0	0.040	0.025	5.4	57	21	nd	nd	nd	11	10	26	63	20
Se02	32	0.08	23	1.7	0.047	nd	6.0	75	23	nd	nd	nd	14	10	45	84	21
Se03	33	0.26	24	1.5	0.047	nd	6.8	54	22	nd	nd	nd	17	10	32	88	17
Se04	33	0.35	32	1.6	0.070	nd	9.3	70	22	nd	nd	nd	8.7	13	30	79	26
Se05	30	0.37	36	1.6	0.059	nd	9.9	70	20	nd	nd	nd	nd	16	17	75	29
Se06	29	0.49	59	1.2	0.064	0.20	8.6	69	26	nd	nd	nd	nd	11	10	159	19
Tr	26	0.39	30	3.0	0.71	nd	18	53	19	nd	nd	nd	0.45	19	12	72	38
Pathumthani																	
Bl02	28	0.50	41	3.4	1.48	nd	25	62	21	nd	nd	nd	nd	26	27	62	49
Bn01	20	0.45	34	1.4	0.21	nd	12	49	21	nd	nd	nd	2.2	16	28	57	46
Bn02	21	0.27	25	1.5	0.10	nd	9.0	44	15	nd	nd	nd	6.5	11	13	43	37
Bn03	24	1.58	25	1.3	0.044	nd	5.1	79	20	nd	nd	nd	6.5	10	27	58	21
Cc01	30	0.16	37	3.6	0.14	nd	12	66	16	nd	nd	nd	0.40	17	26	50	34
Cc02	29	0.40	22	3.3	0.14	nd	9.8	62	18	nd	nd	nd	11	15	29	44	29
Ok	27	0.32	47	1.7	0.057	nd	6.2	63	17	nd	nd	nd	nd	10	28	89	19
Rs02	30	0.63	33	1.6	0.062	nd	6.9	58	16	nd	nd	nd	12	11	28	60	22
Rs03	25	0.42	31	2.1	0.12	nd	8.3	58	22	nd	nd	nd	nd	12	28	58	27
Se07	24	0.87	31	1.6	0.062	nd	4.3	58	18	nd	nd	nd	4.6	7.5	27	53	21
Tan01	27	0.24	35	2.2	0.074	nd	7.0	66	16	nd	nd	nd	6.0	11	28	56	21
Tan02	21	0.43	28	1.3	0.065	nd	8.6	54	20	nd	nd	nd	15	11	33	62	15
All sample	30±7	0.4±0.3	32±8	2±0.7	0.2±0.3	0.02±0.07	11±5	65±10	23±8	nd	nd	nd	5±5	15±6	27±7	79±33	32±13
Ayutthaya	33±7	0.4±0.3	32±9	2±0.6	0.3±0.2	0.03±0.08	12±5	68±10	26±8	nd	nd	nd	4±5	17±5	27±9	94±35	35±13
Pathumthani	25±4	0.5±0.4	32±7	2±0.9	0.2±0.4	nd	10±5	60±9	18±2	nd	nd	nd	5±5	13±5	27±5	58±12	28±11
STSD–3 (n=4)	17±0.8	0.9±0.3	39±2	8±0.3	3±0.1	0.4±0.1	17±2	51±3	33±0.9	nd	nd	nd	28±0.6	25±3	36±8	85±7	173±6
Recommended Values [A]			34			1	14	34	38				7	25	39	61	192
Critical soil concentration [B]					<1.8	<37		<300		<3.9	<23	<390		<1,600	<400		

nd = non detectable.

* Subsurface soils represented mean values of 20–60 cm and 60–100 cm depth intervals.

[A] Recommended values of STSD–3 for partial extraction elements by HNO_3 – HCl (CANMET Mining and Mineral Sciences Laboratories, 2011).

[B] Critical soil concentrations of heavy metals for habitat and agricultural use, Pollution Control Department of Thailand (Pollution Control Department, 2004).

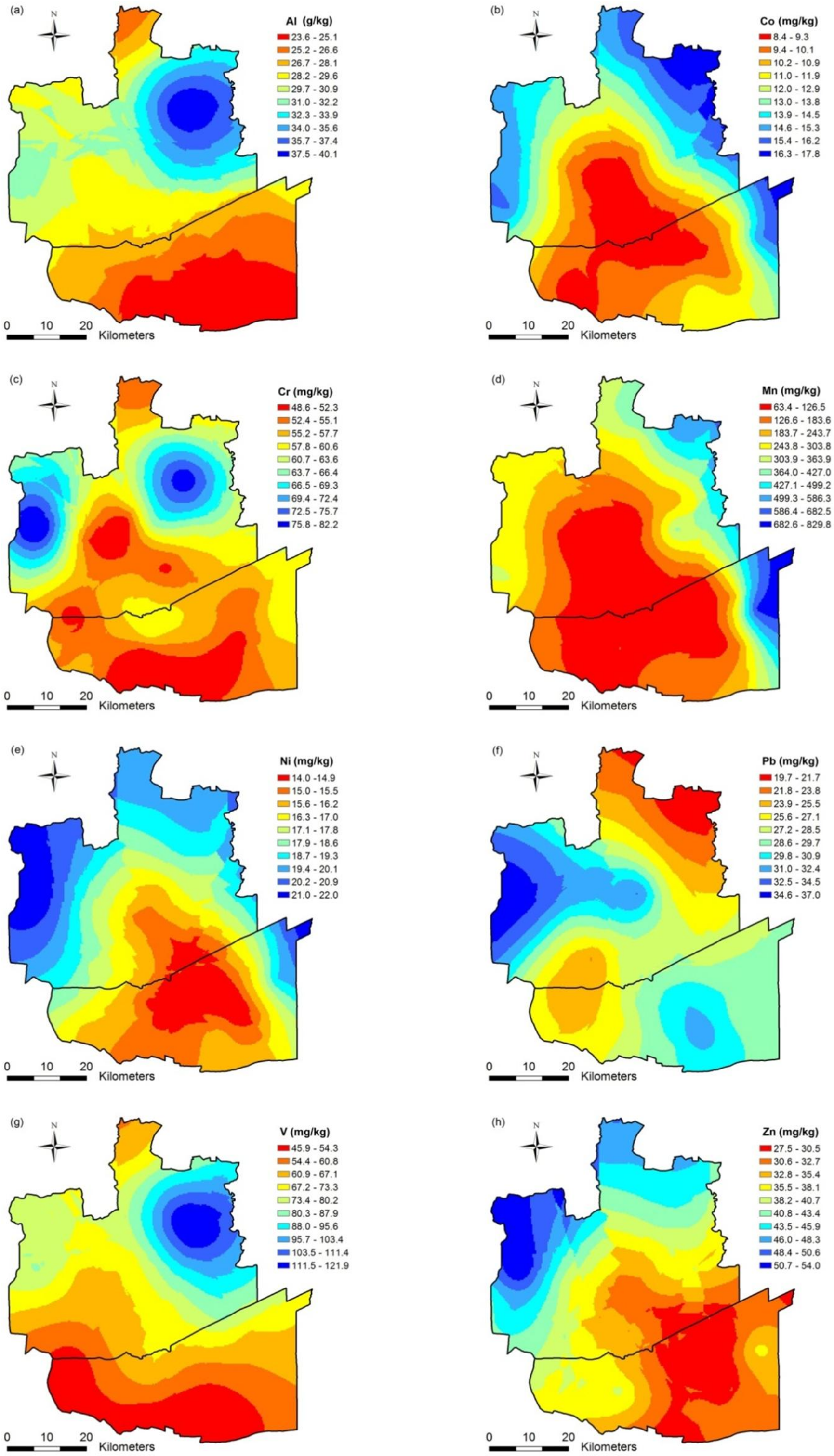

Figure 2: Spatial distribution maps of eight potentially toxic elements.

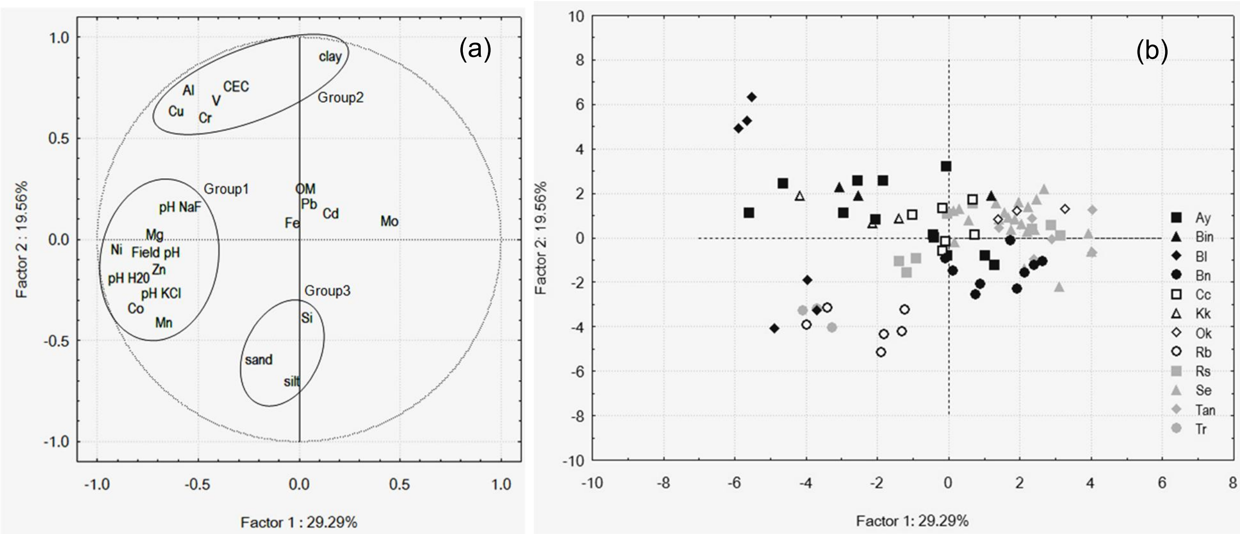

Figure 3: Factor analysis for standardized element concentrations in whole soil samples of 12 soil series from Phra Nakhon Si Ayutthaya and Pathum Thani provinces
((a) distribution of chemical composition and some soil properties (variables) and (b) distribution of soil samples)).

4. Discussion

Some of the sampling locations are close to industrial estates (Se04, Se05, Se06 and Bl02) and landfill (Ay02) areas. The locations of Se04, Se 05, Se 06 and Bl02 soils are close to Hi–Tech, Bang Pa–In, Rojana and Nava Nakhon Industrial Estates, respectively. Concentrations of toxic elements in these locations did not significantly differ from other soils in the areas, reflecting that the soils might not be affected by chemical leakage that may contain toxic elements (*e.g.*, Cd, Hg, Pb, Ni and Cr) from the 7 industrial estates during the flood disaster in 2011. This may be due to the dilution effects from large volumes of floodwater. The Ay02 soil which is adjacent to the waste disposal area had the highest concentration of several toxic elements (Tables 2 and 3). The result of trace element distribution was not obviously attributed to the flooding, which is consistent with the result of the Tingzhi et al. (2008).

The plot of soil samples in the factor diagram (Figure 3b) showed that the soils can be divided into three groups with several outlier soil samples. The first group was for soil samples that had low pH values; these were the acid sulfate soils such as Ay, Rs, Se and Ok soil series. The second group consisted of soils with high clay content and associated chemical composition (Al, Cu, Cr and V); the soils in this group wereBl01 and some Ay soils. The third group included Rb soil which had high silt content. The maps for Al, Co, Cr, Mn, Ni, Pb, V and Zn are shown in Figure 2. The map for entire elements showed large variation across the sites.

5. Conclusions

This study provided the baseline concentrations of major and trace elements of paddy soils in the flood affected areas in 2011. The magnitudes of potentially toxic trace elements in both surface and subsurface soils of all location were below the standard for the soil quality for habitat and agriculture provided by Pollution Control Department of Thailand. Although, certain sampling locations were near industrial estates and landfill areas, the soils did not have high concentrations of most of the toxic elements. The soil which is close to landfill sites had the highest concentration of several of the toxic elements, which indicates that contaminants from the landfill area may be transported by the floodwater. However, the higher concentrations of several toxic elements in this soil may partly be a consequence of seepage and surface water before the flooding in 2011 and was not necessarily a consequence of the flood disaster. Therefore, the toxic elements in the flood affected areas should be monitored to maintain the soil quality standard. Multivariate analysis indicated that the distribution of soils in the factor diagram were diffused but the soil attributes can be divided into three groups (pH, clay and sand groups) on the basis of elemental composition and general soil properties.

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