Final Report

on

Research on the Distribution of Soil Chemistry and Fe Dynamics In Sanjian Plain for 2005

by

Institute of Applied Ecology,
Chinese Academy of Sciences

Final Report of Joint Research on Distribution of Soil Chemistry and Fe Dynamics in Sanjian Plain for 2005

1. Main contents and accomplishment of our work

1.1 Soil sampling was made for marshy soil with different reclamation histories and different land use, which addresses seven regions with duplicate samplings per each region in Sanjiang plain in 2005. The total number of sampling sites was 14, 7 regions times 2 sites.

The samples were collected vertically from surface to a depth of 1.2 meters with soil coring kit for soil chemical analysis. The soil profile was divided into 6 layers, i.e., 10-20 cm, 20-40 cm, 40-60 cm, 60-90 cm, and 90-120 cm. The total number of soil samples is 84, 14 sampling sites times 6 layers.

1.2 Water samples were tried to collect from 5, 100, several hundred meters away from the main drain ditch of Bielahong River, but failed..

1.3 Some appropriate measures were adopted to ensure the sampling work and analysis to be accurately.

1) GPS technology was used to provide precise geographical positioning.
2) Fresh soil samples were stored in thin wall PVC tubes (transparent, 50X300mm, with lid and bottom, and made by Eijkelkamp) at 0 ~ 4°C to prevent oxygenation during transportation and storage.
3) The collected soil samples were 1mm- and 0.25 mm- sieved without prior drying by using polyethylene sieve to avoid metal contamination.

The main content and accomplishment of our work are shown in the following tables in detail.

2. The explanation of the correlative problems in the research

2.1 According to the contract, soil samples should be collected from each 30 cm to a depth of 5 meters, and the total number of the layers per soil profile should be about 16, but the soils in each sampling site were too sticky to sample.

2.2 The water samples should be taken three times in 2005, according to the project, but the sampling sites were in the paddy fields in south bank of Bielahong River,

about 16, but the soils in each sampling site were too sticky to sample.

2.2 The water samples should be taken three times in 2005, according to the project, but the sampling sites were in the paddy fields in south bank of Bielahong River, where no electric facilities were available. We ordered an irrometer hand vacuum pump from IRROMETER COMPANY in Holand. Because the supplier did not deliver the pump in time, we failed to do sampling due to the water had been drained off in the paddy field. As a result, the physical and chemical properties of the soil solution in the sampling sites didn't be analyzed, and the samples could not be sent to Japan as scheduled in this fiscal year.

2.3 The analysis of soil NO_3^- and NH_4^+ was not illuminated in the draft of the contract. Therefore, all of the soil samples were air-dried after we finished the measurement of Fe^{2+}, Mn^{2+} and total reducing substances.

Table.1: Sampling sites in Sanjiang Plain region

No.		Location	Land use type	Reclamation history	Sampling date
Region 1	Site a	133° 52.987′ E 47° 31.918′ N	Wetland (several hundred meters away from the main drain ditch of Bielahong River, comparative region of paddy field))	Without reclamation	June 17th, 2005
	Site b	133° 52.993′ E 47° 31.918′ N			
Region 2	Site a	133° 53.047′ E 47° 31.609′ N	Paddy field (5 meters away from the main drain ditch of Bielahong River)	10 years	June 17th, 2005
	Site b	133° 52.950′ E 47° 31.605′ N			
Region 3	Site a	133° 53.054′ E 47° 31.673′ N	Paddy field (100 meters away from the main drain ditch of Bielahong River)	10 years	June 17th, 2005
	Site b	133° 53.054′ E 47° 31.672′ N			
Region 4	Site a	133° 30.610′ E 47° 32.272′ N	Paddy field	25 years	June 18th, 2005
	Site b	133° 52.993′ E 47° 31.918′ N			
Region 5	Site a	133° 30.781′ E 47° 32.375′ N	Forest Land (comparative region of upland field)	Without reclamation	June 18th, 2005
	Site b	133° 30.612′ E 47° 32.272′ N			
Region 6	Site a	133° 30.172′ E 47° 35.299′ N	Upland field (soybean)	5 years	June 18th, 2005
	Site b	133° 30.173′ E 47° 35.299′ N			
Region 7	Site a	133° 30.012′ E 47° 35.405′ N	Upland field (soybean)	18 years	June 18th, 2005
	Site b	133° 30.012′ E 47° 35.406′ N			

Table.2: Analytical items and methods, and soil treatments

No.	Analytical item	Soil treatment	Analytical method
1	Fe^{2+}	Fresh	Phenanthroline colorimetry
2	Mn^{2+}	Fresh	Potassium periodate colorimetry
3	Total reducing substances	Fresh	Potassium dichromate oxidation
4	TOC (Total organic carbon)	Drying, sieving	Determined directly on the TOC autoanalyzer
5	TON (Total organic nitrogen)	Drying, sieving	$CuSO_4$-K_2SO_4-H_2SO_4 digestion method
6	pH (H_2O)	Air-dry, sieving	Potentiometric method
7	pH (KCl)	Air-dry, sieving	Potentiometric method
8	Ferric chelate	Drying, sieving	Sodium pyrophosphate extraction method
9	Free iron oxide	Drying, sieving	Sodium hydrosulfite - Sodium citrate - Sodium bicarbonate extraction method (DCB)
10	Ca^{2+}	Air-dry, sieving	EDTA complexometric titration
11	Mg^{2+}	Air-dry, sieving	EDTA complexometric titration
12	Cl^-	Air-dry, sieving	Silver nitrate titration
13	SO_4^{2-}	Air-dry, sieving	EDTA indirect titrimetric method
14	K^+	Air-dry, sieving	Flame photometry
15	Na^+	Air-dry, sieving	Flame photometry
16	Fe	Drying, sieving	Sodium carbonate fusion—Flame atomic absorption spectrophotometry
17	Mn	Drying, sieving	Sodium carbonate fusion—Flame atomic absorption spectrophotometry
18	P	Drying, sieving	Sodium carbonate fusion—Molybdenum antimony anti-colorimetric method
19	Na	Drying, sieving	HF-$HClO_4$ digestion—Flame photometry
20	K	Drying, sieving	HF-$HClO_4$ digestion—Flame photometry
21	Mg	Drying, sieving	Sodium carbonate fusion—Flame atomic absorption spectrophotometry
22	Ca	Drying, sieving	Sodium carbonate fusion—Flame atomic absorption spectrophotometry
23	Al	Drying, sieving	Sodium carbonate fusion—Potassium fluoride substitution—EDTA volumetric method
24	Si	Drying, sieving	Sodium carbonate fusion—Mass metrical method
25	Ti	Drying, sieving	Sodium carbonate fusion—Hydrogen peroxide colorimetry

Table.3: Analytical results for region 1

Analytical items	Soil layer					
	0-10 cm	10-20 cm	20-40 cm	40-60 cm	60-90 cm	90-120 cm
Fe^{2+} ($mg.kg^{-1}$)	131.15	90.60	85.67	140.03	174.71	160.61
Mn^{2+} ($mg.kg^{-1}$)	19.22	12.44	17.48	29.07	118.99	102.24
Total reducing substances ($cmol.kg^{-1}$)	1.22	0.52	0.58	0.56	0.64	0.54
TOC ($g.kg^{-1}$)	51.28	14.82	11.44	3.78	2.91	4.98
TON ($g.kg^{-1}$)	10.44	3.78	2.61	1.14	1.24	1.39
pH (H_2O)	5.15	4.65	4.535	4.29	4.22	4.39
pH (KCl)	4.71	4.03	3.94	3.69	3.63	3.83
Ferric chelate (Fe) ($g.kg^{-1}$)	1.25	0.71	0.68	0.76	1.02	0.79
Free iron oxide (Fe_2O_3) ($g.kg^{-1}$)	4.37	3.52	3.91	5.96	10.35	19.96
Ca^{2+} ($mg.kg^{-1}$)	308.0	102.7	102.7	123.2	143.7	136.9
Mg^{2+} ($mg.kg^{-1}$)	124.6	62.3	37.4	49.8	124.6	96.8
Cl^- ($mg.kg^{-1}$)	19.5	3.5	2.8	1.7	36.9	33.0
SO_4^{2-} ($g.kg^{-1}$)	2.11	0.88	2.09	0.63	1.16	1.42
K^+ ($mg.kg^{-1}$)	16.2	6.6	7.8	8.1	6.3	6.6
Na^+ ($mg.kg^{-1}$)	27.2	11.2	11.0	10.7	8.0	9.1
Fe ($g.kg^{-1}$)	20.65	22.17	22.33	25.28	28.85	36.50
Mn ($g.kg^{-1}$)	0.28	0.24	0.26	0.31	0.37	0.50
P ($g.kg^{-1}$)	0.74	0.44	0.49	0.52	0.59	0.91
Na ($g.kg^{-1}$)	12.50	13.48	14.58	14.08	13.84	13.52
K ($g.kg^{-1}$)	16.51	18.26	19.44	18.69	19.18	18.01
Mg ($g.kg^{-1}$)	5.46	5.42	6.19	5.71	5.74	5.79
Ca ($g.kg^{-1}$)	13.19	7.81	8.90	4.91	8.37	10.66
Al ($g.kg^{-1}$)	86.16	86.79	84.77	85.31	85.99	81.98
Si ($g.kg^{-1}$)	562.54	615.81	623.63	631.10	571.31	679.75
Ti ($g.kg^{-1}$)	1.87	2.11	2.34	2.21	2.06	2.14

Table.4: Analytical results for region 2

Items	Soil layer					
	0-10 cm	10-20 cm	20-40 cm	40-60 cm	60-90 cm	90-120 cm
Fe^{2+} ($mg.kg^{-1}$)	179.14	143.34	133.01	46.71	34.00	34.06
Mn^{2+} ($mg.kg^{-1}$)	328.45	201.05	133.09	20.40	12.88	13.30
Total reducing substances ($cmol.kg^{-1}$)	3.14	1.10	0.93	0.26	0.21	0.53
TOC ($g.kg^{-1}$)	25.98	21.84	11.97	6.80	5.12	4.39
TON ($g.kg^{-1}$)	4.65	3.51	1.02	1.74	1.19	1.02
pH (H_2O)	4.54	4.58	4.44	4.35	4.46	4.53
pH (KCl)	4.57	4.62	4.54	4.44	4.52	4.57
Ferric chelate (Fe) ($g.kg^{-1}$)	1.58	0.98	0.71	0.33	0.29	0.37
Free iron oxide (Fe_2O_3) ($g.kg^{-1}$)	22.03	21.14	18.79	18.94	18.97	19.17
Ca^{2+} ($mg.kg^{-1}$)	143.7	147.8	102.7	102.7	82.1	156.0
Mg^{2+} ($mg.kg^{-1}$)	498.4	246.7	174.4	199.3	112.1	104.7
Cl^- ($mg.kg^{-1}$)	18.6	9.9	40.3	1.2	1.2	5.5
SO_4^{2-} ($g.kg^{-1}$)	0.90	1.48	1.46	1.82	1.21	1.41
K^+ ($mg.kg^{-1}$)	4.8	3.3	3.0	3.0	2.7	3.6
Na^+ ($mg.kg^{-1}$)	35.5	30.4	29.6	22.6	27.7	33.1
Fe ($g.kg^{-1}$)	30.76	30.81	30.26	39.91	37.58	39.65
Mn ($g.kg^{-1}$)	0.84	1.00	0.60	0.34	0.40	0.45
P ($g.kg^{-1}$)	1.03	0.94	0.76	0.71	0.66	0.78
Na ($g.kg^{-1}$)	15.29	16.33	15.68	12.65	10.90	11.51
K ($g.kg^{-1}$)	18.56	18.01	17.37	17.74	16.74	16.93
Mg ($g.kg^{-1}$)	5.15	5.22	5.30	6.82	6.85	6.78
Ca ($g.kg^{-1}$)	9.56	10.71	9.22	8.62	8.03	10.03
Al ($g.kg^{-1}$)	68.42	67.81	72.28	90.92	90.30	87.90
Si ($g.kg^{-1}$)	642.64	643.14	677.68	549.36	590.61	586.02
Ti ($g.kg^{-1}$)	2.09	2.19	1.99	2.11	2.18	2.08

Table.5: Analytical results for region 3

Analytical items	Soil layer					
	0-10 cm	10-20 cm	20-40 cm	40-60 cm	60-90 cm	90-120 cm
Fe^{2+} ($mg.kg^{-1}$)	199.93	165.93	166.13	61.32	55.05	53.72
Mn^{2+} ($mg.kg^{-1}$)	436.68	212.03	104.94	19.28	22.17	18.09
Total reducing substances ($cmol.kg^{-1}$)	4.06	2.14	1.48	0.49	0.40	0.41
TOC ($g.kg^{-1}$)	27.79	15.51	7.00	9.88	5.84	5.50
TON ($g.kg^{-1}$)	4.52	2.93	1.36	1.28	1.32	1.41
pH (H_2O)	4.63	4.54	4.46	4.51	4.89	5.07
pH (KCl)	4.40	4.29	4.12	4.23	4.22	4.36
Ferric chelate (Fe) ($g.kg^{-1}$)	1.88	0.84	0.54	0.72	0.48	0.37
Free iron oxide (Fe_2O_3) ($g.kg^{-1}$)	17.20	18.10	16.55	19.97	15.99	17.29
Ca^{2+} ($mg.kg^{-1}$)	102.7	61.6	123.2	102.7	164.3	123.2
Mg^{2+} ($mg.kg^{-1}$)	112.1	112.1	74.8	62.3	24.9	49.8
Cl^- ($mg.kg^{-1}$)	36.9	12.5	16.0	19.5	33.4	16.0
SO_4^{2-} ($g.kg^{-1}$)	1.16	0.65	0.75	0.83	2.01	2.26
K^+ ($mg.kg^{-1}$)	12.0	4.5	3.6	4.2	4.5	6.9
Na^+ ($mg.kg^{-1}$)	34.5	33.4	36.6	45.3	41.5	46.6
Fe ($g.kg^{-1}$)	27.37	32.12	28.16	28.37	32.57	36.80
Mn ($g.kg^{-1}$)	0.77	1.04	0.32	0.38	0.32	0.35
P ($g.kg^{-1}$)	1.12	0.86	0.70	0.73	0.67	0.64
Na ($g.kg^{-1}$)	14.82	15.29	15.84	15.09	13.36	12.61
K ($g.kg^{-1}$)	16.49	17.94	19.47	19.33	18.80	17.90
Mg ($g.kg^{-1}$)	4.98	5.43	5.40	5.62	6.49	6.84
Ca ($g.kg^{-1}$)	6.43	8.43	7.45	8.13	7.36	7.84
Al ($g.kg^{-1}$)	68.20	68.40	76.51	78.81	86.99	91.43
Si ($g.kg^{-1}$)	639.90	664.21	646.03	634.42	603.37	590.49
Ti ($g.kg^{-1}$)	2.08	2.03	2.56	1.99	1.96	2.06

Table.6: Analytical results for region 4

Analytical items	Soil layer					
	0-10 cm	10-20 cm	20-40 cm	40-60 cm	60-90 cm	90-120 cm
Fe^{2+} ($mg.kg^{-1}$)	207.90	172.97	67.07	33.46	29.25	28.14
Mn^{2+} ($mg.kg^{-1}$)	40.07	20.33	13.03	25.69	17.21	11.11
Total reducing substances ($cmol.kg^{-1}$)	6.22	1.39	0.15	0.41	0.04	0.27
TOC ($g.kg^{-1}$)	43.89	30.55	4.83	4.28	2.94	2.36
TON ($g.kg^{-1}$)	9.25	7.48	2.64	1.95	1.85	1.40
pH (H_2O)	4.82	4.75	4.77	4.69	4.68	4.68
pH (KCl)	4.66	4.65	4.73	4.61	4.60	4.63
Ferric chelate (Fe) ($g.kg^{-1}$)	2.21	1.85	0.49	0.25	0.16	0.21
Free iron oxide (Fe_2O_3) ($g.kg^{-1}$)	14.74	10.55	25.10	19.96	11.87	20.36
Ca^{2+} ($mg.kg^{-1}$)	184.8	123.2	102.7	61.6	131.4	82.1
Mg^{2+} ($mg.kg^{-1}$)	199.3	99.7	87.2	87.2	107.1	49.8
Cl^- ($mg.kg^{-1}$)	27.3	5.5	14.2	5.5	9.9	14.2
SO_4^{2-} ($g.kg^{-1}$)	1.95	0.80	1.13	1.36	1.62	1.20
K^+ ($mg.kg^{-1}$)	11.0	5.7	8.1	7.8	8.7	7.8
Na^+ ($mg.kg^{-1}$)	30.3	41.5	29.9	22.6	17.4	16.1
Fe ($g.kg^{-1}$)	25.13	23.49	37.32	33.99	29.90	38.39
Mn ($g.kg^{-1}$)	0.20	0.44	0.20	0.22	0.23	0.33
P ($g.kg^{-1}$)	0.74	0.57	0.49	0.37	0.28	0.59
Na ($g.kg^{-1}$)	13.61	14.80	13.39	14.81	13.75	14.71
K ($g.kg^{-1}$)	18.89	19.46	20.79	21.76	20.82	21.25
Mg ($g.kg^{-1}$)	5.16	5.14	5.85	6.02	5.85	6.52
Ca ($g.kg^{-1}$)	5.14	5.36	4.53	4.55	7.05	8.62
Al ($g.kg^{-1}$)	76.23	76.56	89.09	82.78	90.36	88.42
Si ($g.kg^{-1}$)	601.54	612.62	608.91	614.86	620.49	616.62
Ti ($g.kg^{-1}$)	2.02	2.08	1.81	1.53	2.07	2.07

Table.7: Analytical results for region 5

Analytical items	Soil layer					
	0-10 cm	10-20 cm	20-40 cm	40-60 cm	60-90 cm	90-120 cm
Fe^{2+} ($mg.kg^{-1}$)	197.34	161.33	156.49	143.97	128.36	123.14
Mn^{2+} ($mg.kg^{-1}$)	15.14	10.19	22.81	6.05	6.96	6.26
Total reducing substances ($cmol.kg^{-1}$)	1.19	1.26	1.47	1.24	1.33	0.93
TOC ($g.kg^{-1}$)	80.27	15.57	5.85	5.18	1.63	2.28
TON ($g.kg^{-1}$)	13.46	3.74	1.97	1.96	1.28	1.73
pH (H_2O)	3.83	3.88	3.94	4.39	4.41	4.56
pH (KCl)	3.87	3.96	4.06	4.49	4.52	4.58
Ferric chelate (Fe) ($g.kg^{-1}$)	3.16	1.11	0.45	0.26	0.21	0.19
Free iron oxide (Fe_2O_3) ($g.kg^{-1}$)	14.36	21.47	12.90	13.39	12.79	13.35
Ca^{2+} ($mg.kg^{-1}$)	34.9	32.9	53.4	32.9	73.9	94.5
Mg^{2+} ($mg.kg^{-1}$)	360.1	299.0	286.6	249.2	199.3	37.2
Cl^- ($mg.kg^{-1}$)	157.3	123.6	43.5	24.7	27.8	19.8
SO_4^{2-} ($g.kg^{-1}$)	2.28	2.27	1.23	1.20	1.26	1.31
K^+ ($mg.kg^{-1}$)	29.5	5.4	4.8	5.4	5.1	6.2
Na^+ ($mg.kg^{-1}$)	22.6	8.9	10.0	12.4	10.0	10.0
Fe ($g.kg^{-1}$)	29.21	35.42	30.56	32.89	34.76	32.04
Mn ($g.kg^{-1}$)	0.26	0.19	0.16	0.23	0.28	0.36
P ($g.kg^{-1}$)	1.07	0.48	0.49	0.43	0.24	0.28
Na ($g.kg^{-1}$)	11.97	12.15	13.89	13.36	12.75	13.22
K ($g.kg^{-1}$)	16.63	18.52	19.28	19.34	19.15	18.79
Mg ($g.kg^{-1}$)	5.10	5.72	6.03	6.55	6.76	7.04
Ca ($g.kg^{-1}$)	5.27	4.93	5.09	3.29	5.22	8.43
Al ($g.kg^{-1}$)	68.25	80.34	86.97	87.73	87.68	80.58
Si ($g.kg^{-1}$)	575.01	664.40	675.74	632.81	613.35	622.57
Ti ($g.kg^{-1}$)	2.17	2.23	2.34	2.28	2.42	2.53

Table.8: Analytical results for region 6

Analytical items	Soil layer					
	0-10 cm	10-20 cm	20-40 cm	40-60 cm	60-90 cm	90-120 cm
Fe^{2+} ($mg.kg^{-1}$)	76.88	49.68	101.58	54.65	58.35	55.04
Mn^{2+} ($mg.kg^{-1}$)	9.08	11.56	16.30	11.33	14.34	10.17
Total reducing substances ($cmol.kg^{-1}$)	0.66	0.76	1.07	0.85	0.70	0.43
TOC ($g.kg^{-1}$)	14.55	9.91	18.43	12.69	11.06	7.85
TON ($g.kg^{-1}$)	5.28	3.24	5.11	3.40	3.20	2.68
pH (H_2O)	4.38	4.22	4.385	4.51	4.43	4.58
pH (KCl)	4.44	4.38	4.37	4.46	4.37	4.52
Ferric chelate (Fe) ($g.kg^{-1}$)	0.66	0.57	0.70	0.60	0.51	0.48
Free iron oxide (Fe_2O_3) ($g.kg^{-1}$)	15.39	18.48	12.85	14.03	14.63	16.31
Ca^{2+} ($mg.kg^{-1}$)	443.5	135.5	94.5	135.5	156.0	115.0
Mg^{2+} ($mg.kg^{-1}$)	473.4	348.9	186.9	211.8	186.9	199.3
Cl^- ($mg.kg^{-1}$)	60.2	17.4	17.4	10.8	11.8	38.3
SO_4^{2-} ($g.kg^{-1}$)	2.45	1.48	1.16	1.56	1.58	1.79
K^+ ($mg.kg^{-1}$)	32.9	9.2	8.7	8.4	8.2	7.9
Na^+ ($mg.kg^{-1}$)	21.5	15.8	17.6	14.0	11.9	11.9
Fe ($g.kg^{-1}$)	35.37	37.63	25.98	34.25	33.04	35.10
Mn ($g.kg^{-1}$)	0.29	0.41	0.25	0.25	0.31	0.35
P ($g.kg^{-1}$)	0.89	0.74	0.78	0.75	0.59	0.67
Na ($g.kg^{-1}$)	11.60	12.00	12.56	11.99	12.51	12.32
K ($g.kg^{-1}$)	16.13	17.74	18.50	18.12	18.57	18.19
Mg ($g.kg^{-1}$)	6.31	6.60	6.41	6.42	6.21	6.24
Ca ($g.kg^{-1}$)	6.72	7.34	7.27	7.22	6.96	8.07
Al ($g.kg^{-1}$)	67.64	83.24	83.99	86.99	86.42	85.60
Si ($g.kg^{-1}$)	590.89	583.41	582.30	586.05	589.95	605.82
Ti ($g.kg^{-1}$)	2.31	2.52	2.03	2.00	1.92	1.77

Table.9: Analytical results for region 7

Analytical items	Soil layer					
	0-10 cm	10-20 cm	20-40 cm	40-60 cm	60-90 cm	90-120 cm
Fe^{2+} ($mg.kg^{-1}$)	136.56	154.74	53.53	37.29	30.46	33.16
Mn^{2+} ($mg.kg^{-1}$)	4.10	6.71	4.49	12.56	4.91	8.27
Total reducing substances ($cmol.kg^{-1}$)	1.34	0.92	0.90	0.85	0.36	0.19
TOC ($g.kg^{-1}$)	25.44	25.39	10.28	6.71	4.05	3.46
TON ($g.kg^{-1}$)	7.61	5.84	3.87	2.49	1.80	1.76
pH (H_2O)	4.16	4.19	4.42	4.56	4.66	4.73
pH (KCl)	4.04	4.12	4.34	4.41	4.48	4.56
Ferric chelate (Fe) ($g.kg^{-1}$)	1.28	1.60	0.54	0.17	0.26	0.22
Free iron oxide (Fe_2O_3) ($g.kg^{-1}$)	17.58	16.87	24.87	19.84	18.63	15.29
Ca^{2+} ($mg.kg^{-1}$)	402.4	135.5	135.5	82.1	61.6	61.6
Mg^{2+} ($mg.kg^{-1}$)	523.3	224.3	261.6	24.9	49.8	87.2
Cl^- ($mg.kg^{-1}$)	45.2	24.4	20.9	63.4	31.6	36.0
SO_4^{2-} ($g.kg^{-1}$)	2.07	1.79	1.59	1.13	1.07	1.16
K^+ ($mg.kg^{-1}$)	13.8	5.6	5.8	4.6	4.1	5.3
Na^+ ($mg.kg^{-1}$)	17.2	17.4	18.6	19.2	14.9	16.0
Fe ($g.kg^{-1}$)	26.96	26.16	38.90	37.81	37.55	36.66
Mn ($g.kg^{-1}$)	0.38	0.41	0.32	0.26	0.27	0.34
P ($g.kg^{-1}$)	1.03	0.93	0.89	0.69	0.71	0.56
Na ($g.kg^{-1}$)	14.03	14.01	12.19	12.17	11.25	13.68
K ($g.kg^{-1}$)	17.70	19.34	20.04	20.35	19.58	20.39
Mg ($g.kg^{-1}$)	5.84	5.04	6.31	6.80	7.00	6.96
Ca ($g.kg^{-1}$)	7.26	6.72	7.26	5.99	4.98	6.95
Al ($g.kg^{-1}$)	74.42	70.95	86.29	92.90	91.68	89.98
Si ($g.kg^{-1}$)	630.41	626.91	602.58	581.80	564.38	588.47
Ti ($g.kg^{-1}$)	1.82	2.24	2.12	2.18	2.09	2.18

Executor

Signature Chen Xin

Chen Xin

Institute of Applied Ecology,

Chinese Academy of Sciences

P. O. Box 417

Shenyang 110016, CHINA

Phone: +86-24-83970318; Fax: +86-24-83970300