Changes of soil chemical properties and heavy metal contents on periodical monitoring arable lands in ChungBuk, Korea

Young-Sang Kim[A], Gyeong-Ja Lee, Se-Kyun Shin, In-gyu Song and Sang-Gun Ha[B]

[A]ChungBuk Provincial Agricultural Research and Extension Services, Cheongweon 383. Korea. Email suanbo@korea.kr
[B]National Academy of Agricultural Science, Suwon 441-707, Republic of Korea, Email ha0sk@korea.kr

Abstract
Studies were conducted to provide basic data for production of safe agricultural products by reducing soil and water pollution, and to establish soil improvement and fertilization policy for environmentally friendly agriculture. This is a long-term benchmark investigation of soil chemical properties and heavy metal contents in ChungBuk arable land. The obtained data showed the soil chemical properties and heavy metal contents of the same sites every 4 years since 1999. The investigated lands were upland(180), plastic film house(108), paddy (220 sites), and orchard soil(150) according to the form of agriculture. The chemical properties of upland soil in 2009 showed increases in pH, electric conductivity (EC), Ca, and Mg compared with 2001, and the organic matter (OM) contents were not changed, while Av. P_2O_5 and K decreased. The cadmium (Cd) had the same level, copper (Cu), nickel (Ni), zinc (Zn), arsenic (As) contents increased but lead (Pb), and chrome (Cr) decreased. The chemical properties of plastic film house soil in 2008 showed increases in pH, OM and Ca compared with 2000, while EC, Av.P_2O_5, K, Mg, and NO_3-N had decreased. The As content increased, but Cd, Cr, Cu, Ni, Pb, Zn decreased in plastic film house soil. The chemical properties of paddy soil in 2007 showed increases in pH, OM, Av.P_2O_5, Av.SiO_2, Ca, and Mg compared with 1999, but K slightly decreased. The contents of Cu, Ni, Pb, Zn and As increased, but the Cd and Cr decreased in paddy soil. For orchard soil in 2006 pH, EC, OM, Av.P_2O_5, K, and Ca increased compared with 2002, but lime requirement decreased. Cd, Cr, Cu, Ni, Zn, and As increased, but Pb decreased in orchard soil. Soil fertility was improved by increasing pH, OM, Ca, and amounts of Av.SiO_2, and decreasing the lime requirement. Only 9-26% of investigated sites, however, remained in the optimum nutrient range, so nutrient imbalance of soil became more common. The heavy metal contents of the soils were less than amounts stipulated by regulation of the Soil Environment Conservation Law (SECL), but sustained soil monitoring should be carried out due to the gradual increase of heavy metal contents.

Key Words
Arable land, soil chemical properties, heavy metal, monitoring.

Introduction
The demands for environmentally friendly agriculture products are increasing due to the pollution of environment, and soil pollution by heavy metals, their translocation into rice and threats to human health through the food chain are important concerns (Yang 2007). The problems of secondary environmental pollution and safety of agricultural products in technology intensive agriculture are known and a benchmark investigation is needed to provide data on soil improvement and fertilization for the production of environmentally friendly agricultural products. Every country in the world including international organizations are reinforcing the regulation of pollution of soil, water, and agricultural products. Soil survey projects are being conducted for agriculture policy in EU(EEA Report No2. 2006), and a blueprint exists for monitoring soil changes for scientific purpose at the farm, catchment, region, state or national level in Australia (Natural Resource Topics 2007). An Internet and GIS-based Environmental Monitoring System (IGUS) is being operated for soil monitoring sites for soil conservation and protection purposes, as well as for environmental monitoring and reporting in Germany (Schröder *et al.* 2006). Also, investigations of soils, is part of large projects concerning environmental monitoring, water erosion, protection of water resources, physical and geographical investigations in Poland. In Korea, a soil information system (RDA, http://asis.rda.go.kr) based on national soil database was established and is utilized by researchers and farmers, and a database of soil chemical properties, water quality, vegetation, and aquatic living things is being accumulated. The Ministry for Food, Agriculture, Forestry and Fisheries(MFAFF) has investigated and established data for agriculture land reports and cultivation conditions (Korea Rural Corporation, http://gis.ekr.or.kr), and data of bio-species, topographic landscape information, and vegetation linked with a geographical information system (Minister of Environment, http://eiass.go.kr) on the internet. The establishment of arable land soil information is urgent for the production of safe agricultural products

through sustained soil management in environmentally friendly agriculture. In order to establish measurements for the improvement of fertilization systems and conservation of the agricultural environment, the annual soil information from 1999 to 2009 in ChungBuk, Korea was analysed.

Methods

The arable lands in ChungBuk are classified as 4 groups (paddy, upland, plastic film house, and orchard soil), and the same sites were investigated every 4 years. The soils investigated were top soil (0-20cm) in paddy and upland, while the top soil and deeper soil (20-40cm) were surveyed for plastic film house and orchard soil. The 12 counties in ChungBuk were targeted, and the numbers of investigation were 220 sites in paddy, 180 sites in upland, 108 sites (top soil 108 sample, and depth soil 108 samples) in plastic film house, and 150 sites (top soil 150 sample, and depth soil 150 samples) in orchard. The survey cycle was every 4 years in the order paddy, upland, plastic, and orchard soil. 10 soil characteristics were investigated including pH, and 7 heavy metals. Soil chemical properties including pH were analysed according to the protocol of the NIAST(National Institute of Agricultural Science and Technology 2000), and the contents of Cd, Cr, Cu, Pb, Ni and Zn in each sample were measured by Inductively Coupled Plasma(ICP, Varian vistra pro) after 0.1N HCl extraction. The content of As was also measured with the same technique after 1N-HCl extraction

Results

For upland soil in 2009 pH, EC, Ca, and Mg had increased compared with 2001, and OM contents were not changed, while Av.P_2O_5 and K slightly decreased and lime requirement had decreased by 50%. According to NIAST (2003), heavy metal pollution in soil is caused by many kinds of pollutants which leak from industrial complexes or abandoned metalliferous mines. Metal contents in upland soil had increased for Cu, Ni, Zn, and As, soils had the same level of Cd, Cr and Pb had decreased compared with 2001. For plastic film houses in 2008 values had increased, for pH, OM, and Ca, whereas Av.P_2O_5, EC, K, NO_3-N, and Mg decreased compared with 2001. Jung *et al*. (1995) reported that the composts containing industrial waste have caused heavy metal pollution in plastic house soil. In this study, heavy metal contents were also higher in plastic film house soil compared with open fields.

Table 1. Changes of average soil chemical properties in ChungBuk arable land.

Division	Year	pH (1:5)	OM (g/kg)	Av. P_2O_5 (mg/kg)	EC (dS/m)	Ex. Cat. ($cmol_c$/kg) K	Ca	Mg	Av. SiO_2 (mg/kg)	NO_3-N (mg/kg)	LR* (kg/ha)
Upland soil	2009	6.2	18	435	0.7	0.58	6.8	1.9	-	-	640
	2001	5.9	18	500	0.5	0.59	5.6	1.6	-	-	1,360
Plastic film house soil	2008	6.5	30	1,002	3.9	1.31	9.8	2.9	-	177	650
	2000	6.2	27	1,116	4.6	1.67	8.7	3.6	-	189	-
Paddy soil	2007	5.9	20	129	-	0.21	4.0	1.0	116	-	-
	1999	5.5	19	126	-	0.22	3.6	0.9	78	-	-
Orchard soil	2006	6.2	24	422	0.6	0.71	5.4	1.3	-	-	800
	2002	6.0	16	362	0.5	0.52	5.1	1.5	-	-	1,030

*LR : Lime requirements

Six heavy metals (Cd, Cr, Cu, etc.) except for As had decreased in concentration, and this might be caused by application of high quality composts for production of environmentally friendly agricultural products. The pH, OM, Av.P_2O_5, Ca, Mg, and Av.SiO_2 values increased for the paddy soil in 2007, especially Av.SiO_2 increased drastically compared with 1999. This might be attributed to supply of silicic acid fertilizer under government policy. The contents of K were low but there were no significant differences. The heavy metal contents of paddy soil in 2007 were lower for Cd and Cr, and higher for Cu, etc. compared with 1999. The Mg contents and lime requirements in 2006 decreased for orchard soil compared with 2002, and other elements increased. In the analysis of heavy metal contents of orchard soil in 2006, the Pb contents decreased while six heavy metals including Cd increased. These results are coincident with the report of Jung *et al.* (1997) who tested livestock manure fertilizer. The heavy metal contents were much lower than concern and action levels for soil pollution under environmental conservation law (Kim *et al.* 2008), and these data were very similar to those in Jung's report (1997). We classified data for arable land into 3 groups, over range, proper range and under range. Only 23% of pH, 25% of OM, 26% of Av.P_2O_5, 11% of K, 9% of Ca and 16% of Mg values for upland soil in 2009 were seriously unbalanced with little change over time.

Table 2. Changes of average contents of extractable heavy metals in ChungBuk arable land.

Division	Year	Cd (ppm)	Cr (ppm)	Cu (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	As (ppm)
Upland soil	2009	0.07	0.24	3.76	0.63	2.35	10.23	0.94
	2001	0.07	0.61	3.14	0.61	3.13	9.21	0.06
Plastic film house soil	2008	0.07	0.43	3.42	0.78	1.09	26.83	0.55
	2000	0.10	0.73	4.25	1.08	2.45	27.25	0.09
Paddy soil	2007	0.06	0.41	3.17	0.53	5.07	1.76	1.13
	1999	0.24	1.57	0.26	0.26	3.09	1.47	0.75
Orchard soil	2006	0.07	0.72	3.23	0.83	2.79	13.03	0.13
	2002	0.06	0.56	2.95	0.64	2.93	7.96	0.06
Concern level†		1.5	4	50	40	100	300	6
Action level†		4	10	125	100	300	700	15

† Soil Environmental Conservation Law of Korea (Ministry of environment 1996).

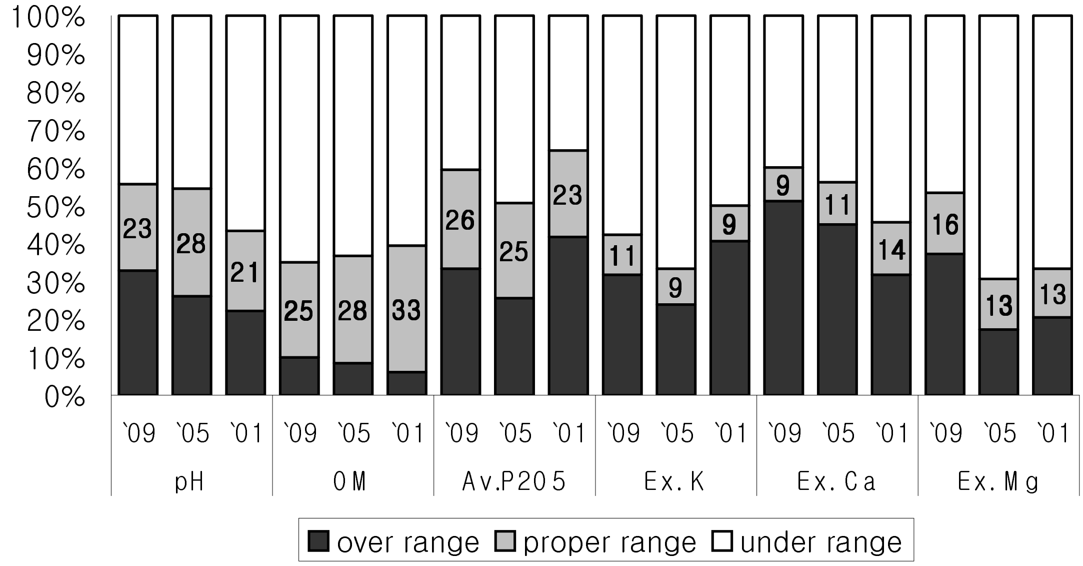

Figure 1. Distribution of chemical properties in ChungBuk arable soil.
* Proper range in upland soil: pH (6.0-6.5), OM(20-30g/kg), Av.P_2O_5(300-500g/kg), K(0.50-0.60 $cmol_c$/kg), Ca(5.0-6.0 $cmol_c$/kg), Mg(1.5-2.0 $cmol_c$/kg)

Conclusion

For the analysis of soil chemical properties, we determined that there were significant differences over time for paddy, upland, plastic film house, and orchard soil in ChungBuk. The pH, OM, and Ca contents increased, and the lime requirements of soil decreased. These results were caused by the government's supply policy for soil ameliorants. The heavy metal contents of soil gradually increased, and this might be caused by application of food waste compost, factory livestock manure fertilizer and soil pollutant materials etc. The optimum ranges of chemical properties of upland soil were classified as under, proper, and over range, and the nutritional imbalance problems were sometimes very serious. Thus a soil improvement and fertilizer application policy should be established by the government sector with technical support. Sustained benchmark investigations of soil are needed to establish environmentally friendly agriculture systems, and to produce safe agricultural products under scientific soil management.

References

EEA Report No 2 (2006) Integration of environment into EU agriculture policy-The IRENA indicator-based assessment report. http://www.eea.europa.eu./publications/eea report 2006 2.

Jung GB, Jung KY, Cho GH, Jung BG, Kim KS (1997) Heavy metal contents in soils and vegetables in the plastic film house. *Korean Soc. Soil Sci. Fert*. **30**(2), 152-160.

Jung KY (1998) Organic wastes recycling. *Korean Soc. Soil Sci. Fert*. Vol. special issue (113-120).

Ministry of Environment (1996) Soil Environment Conservation Work Concordance. pp. 143-358.

Natural resource management issues facing Australian agriculture: Natural Resource topics (2007). http://www.anra.gov.au/topics/index.html.

National Institute of Agricultural Science and Technology (NIAST) (2000) Method of Soil and Plant body analysis. pp.103-147.

National Institute of Agricultural Science and Technology (NIAST) (2003). Survey on the change of heavy metal contents and chemical properties in the vulnerable agricultural fields for environmental contamination : Monitoring project on agri-environment quality in Korea. pp. 59-108.

Bialousz S, Marcinek J, Stuczynski T, Turski R (2009) Soil survey, soil monitoring and soil databases in Poland. *European soil bureau*. Research Report No. **9**, 263-273.

Schröder W, Pesch R, Schmidt G (2006) Soil monitoring in Germany: spatial representativity and methodical comparability. http://www.cababstractsplus.org/abstracts/Abstract.

Kim WI, Kim MS, Kim YS (2008) Long-term monitoring of heavy metal contents in paddy soils. *Korean J. Soil Sci. Fert.* **41**(3), 190-198.

Yang JE, Ok YS, Kim WI, Kim JS (2007) Heavy metal pollution, risk assessment and remediation in paddy soil environment: Research experiences and perspectives in Korea. 8th Conference of East and Southeast Asian Federation of Soil Science. *ESAFS 8*. Tsukuba, Japan .pp. 44-49.