C-052 Synthetic Evaluation of the Effect of Acidic Load on Material Flows in East Asian Catchments Areas（Abstract of the Final Report）

Contact person Junko Shindo
Senior researcher, Carbon and Nutrient Cycles Division
National Institute for Agro-Environmental Sciences
Kannondai 3-1-3,Tsukuba,Ibaraki,305-8604 Japan
Tel:+81-29-838-8225 Fax:+81-29-838-8225
E-mail:shindo@niaes.affrc.go.jp

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[Abstract]

In order to evaluate the effect of atmospheric nitrogen deposition onto the soil and stream water chemistry in East Asia, field measurements were carried out. With a newly developed method by using ion exchange resin, yearly nitrogen deposition in several sites in China and Thailand was measured. Deposition amount showed pronounced regional variations and it was extremely high in Dinghushan in Guangdong province located in sub-tropical area with acidic soil. Soil and stream water were extremely acidic and much nitrate ions were exported to the stream. Comparing the measurements at the sites with same soil and vegetation types receiving less acidic deposition, Dinghushan was considered to be acidified by the acidic deposition. Sakaerat site in Thailand has the same soil type and soil was also acidic while the nitrate leaching was very low. Acidic deposition, internal cycle and external output of chemical elements showed the marked seasonal variation and they were regulated by the water budget through the clear dry and rainy seasons.

In order to predict the future nitrogen deposition and nitrogen leaching, the changes in food demand and supply in East Asian countries, especially in China, were investigated based on the various statistics and GIS data. Based on the results, ammonia emission rates from agriculture were estimated up to 2030. Ammonia emission rate was predicted to become twice in 2030, mainly due to the increase of per capita meat consumption. And nitrogen concentration in stream water was estimated to increase along the east coast of China, around the lower leach of the Changjiang River, and Viet Nam in the next 10 to 20 years. Selection of the scenario on food trade was very important and emission rate reduced to 84% when additional feed in the future was assumed to be imported.

1. Introduction

In East Asia, the consumption of food and energy has been increasing markedly because of the rapid economic development and the population growth. These changes have enhanced the emission of acidic substances including reactive nitrogen. Too much reactive nitrogen caused serious environmental pollution such as nitrate pollution, eutrophication etc. Asia is regarded as a hotspot of nitrogen mobilization[1].

Reactive nitrogen affects material balances in natural ecosystems through atmospheric deposition. "Nitrogen saturation" accompanied with soil and stream water acidification in forests has been intensively studied in Europe and America[2]. In East Asia, however, data on acidic deposition, internal cycling and external leaching and the relationship among them are still insufficient in spite of the high emission of reactive nitrogen. Catchment-scale monitoring and analysis are considered to provide efficient data to evaluate the effects of acidic deposition and such measurements are expected to realize in some areas in East Asia.

Social and economic situations in East Asia are now changing. Economic growth is quite high. Many people living in rural area have immigrated to urban area and such trend will be stimulated. These social changes will affect the acidic deposition and nitrogen cycle in East Asia.

２. Research Objective

The objective of the study is to estimate the present and the future status of acidic deposition and material cycle in natural ecosystems based on field measurements and mass balance modeling. As ammoniacal substances due to agriculture are the major acidic substances, the future scenarios of food demand and supply are also investigated. The study area is 'East Asia'. This research also has a mission to provide information to make a monitoring guideline for catchment analysis in the tropical ecosystems for Acid Deposition Monitoring Network in East Asia (EANET).

３. Research Method and Result

Several areas were selected as study sites in China and Thailand with different meteorological, soil and vegetation conditions (Table 1) and measurements of acidic deposition, soil and stream water chemistry were conducted. For the references, measurements were made in several Japanese catchment areas.

Table 1 Study sites in China and Thailand

Study site			Latitude	Longitude	Altitude m	Precipitation	Temperature	Soil
China	Jilin	Changchun	43°47′	125°29′		584	5.2	Phaeozems
		Chanbaishan	42°23′	128°06′	771	570	3.5	Lithosols
	Guangdong	Dinghushan	23°09′	112°32′	148～246	1927	21.0	Acrisols
		Heishinding	23°27′	111°53′	451～509			Acrisols
	Guangxi	Dayaoshan						Acrisols
	Inner Mongolia	Hailar	50°53′	121°30′	805	352		
	Beijing	Lingshan	39°57′	115°25′	1233～1304	578		Lithosols
Thailand	Sakaerat		14°27′ -14°33′	101°53′ -101°56′	200～760	1260	26.0	Acrisols

(1) Measurement of atmospheric nitrogen deposition by using ion exchange resin columns

A new sampling method using ion exchange resin was developed to measure the long-term average of acidic deposition. Ion exchange resin columns were set in several places in Nagano prefecture to examine the measurement accuracy. Absorption efficiencies by resin were 96% and 97% for NO3-N and NH4-N, respectively.

By using the ion exchange resin columns, nitrogen (ammonium and nitrate) deposition rates were measured in 6 forest areas in China (Hailar, Chanbaishan, Changchun, Beijing, and Guangdong (Dinghushan and Heishiding)), at 6 forest sites in Nagano in Japan, and one forest in Sakaerat in Thailand. The annual nitrogen deposition rates ranged from 2.5 to 20.7 kg N ha-1 year-1 by rainfall without canopy, and from 1.4 to 39.2 kg N ha-1 year-1 by throughfall in forest areas in China (Fig. 1). The nitrogen deposition rates were higher in southern parts of China with much precipitation, but there was a large variation in the rate with similar precipitation. There was a significant positive relationship between the nitrogen deposition rate and population density, which indicates a large emission of reactive nitrogen accompanying with human activities. Ammonium nitrogen predominated the nitrogen deposition in forest areas having large nitrogen deposition. Nitrogen derived from fertilizer and livestock wastes contributed much to nitrogen deposition, rather than nitrogen (NOx) from factories and automobiles, in the present China.

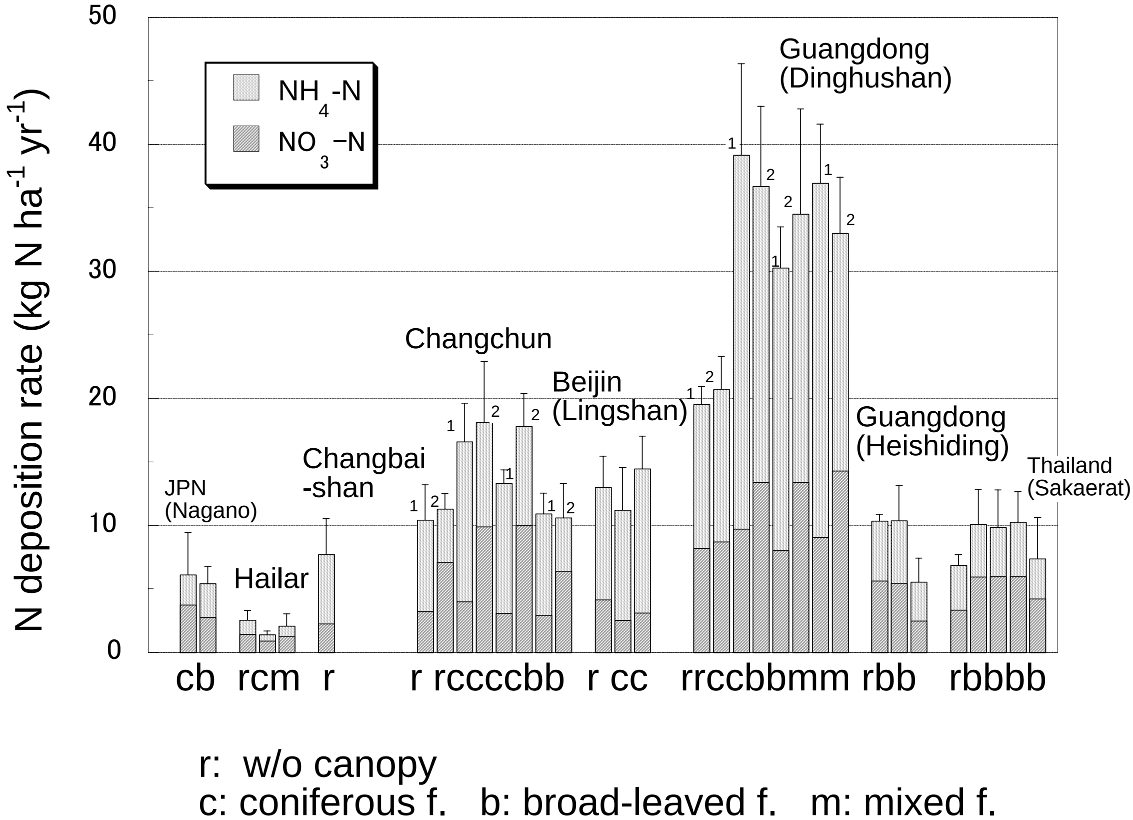

Fig. 1 Nitrogen deposition rates in forest areas in China with those in Japan and Thailand. Numbers above bars indicate the first and second year of the investigation.

(2) Evaluation of characteristics of internal cycles of acidic substances

In order to investigate the ecological response to acidic deposition in different climatic zones, soil chemical properties down to upper mother materials and stream water chemistry were measured in sub-boreal forests (Changbaishan, Changchun), sub-tropical forests (Dinghushan, Heishiding, Dayoshan) in China and a temperate forest (Tokyo).

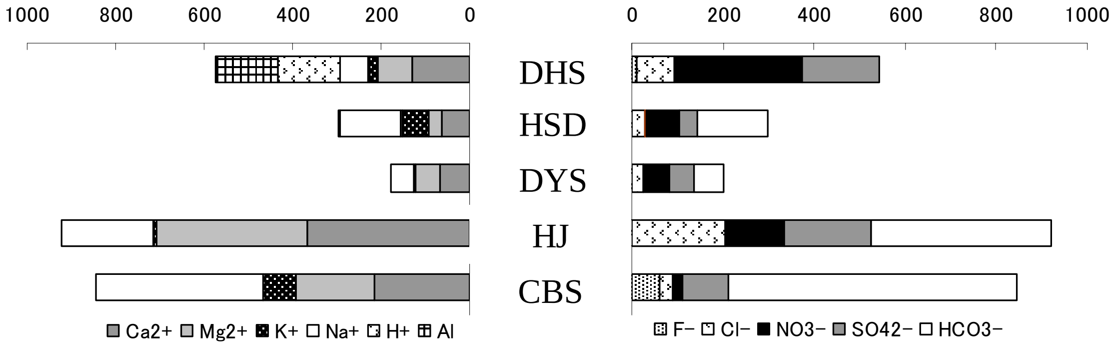

Fig. 3 Ion concentrations of stream water from watersheds at the five sites

DHS: Dinghushan, HSD: Heishiding, DYS: Dayaoshan, HJ: Hochioji in Tokyo. CBS: Changbaishan

Soils in Changbaishan and Changchun contained much base cation and had higher soil pH. Concentration of nitrate and acidity in stream water in Changbaishan was low. In Dinghushan that is 75 km apart from Guangzhou city, soil and stream water showed a pH as low as 4.1 and contained a high concentration of dissolved Al (probably in a form of Al^{3+}) of 2.3 mg L^{-1}. Exchangeable base cations were exhausted from the all soil horizons. In Heishiding and Dayaoshan, which are 150 km and 330 km west of Guangzhou city, soils and stream water were also acidic but less than that in Dinghushan (Fig. 2). Acrisol, which is heavily weathered soil formed under warm and humid climate, is a reason of the acidity in these sub-tropical sites. However, as the atmospheric acidic deposition in Dinghushan is much higher than in other sites, it is strongly suggested that anthropogenic acidic deposition has caused the extreme acidification in Dinghushang.

(3) Estimation of material balance and ecological effects of acidic deposition on tropical seasonal forested catchment in Thailand

A study site for the catchment-scale analysis of elemental cycle was established in a dry-evergreen forest in the Sakaerat Silvicultural Research Station (Sakaerat SRS), in Thailand and field surveys on input (atmospheric deposition), output (discharge from a stream) and biogeochemical processes are carried out at two-week interval in the selected catchment area (approx. 35 ha). To clarify the seasonal-spatial variation of soil acidity, a soil sampling plot (40 m × 350 m) was set up and soil samples were collected in the end of rainy season and in dry season. Nitrogen (N) mineralization, nitrification and input-output fluxes of N within the soil were determined using in situ incubation method and ion exchange resin method. Atmospheric input and stream water output of elements were regulated by sub-tropical climate with clear dry and rainy season, and by high-weathered acidic soil (Fig. 3): It was suggested that air pollutants including much SO_4^{2-} and NO_3^- were suspended in the atmosphere during dry season and washed out by the first precipitations in the beginning of wet season. Cations accumulating in soil layer leached out in this season. The pH-dependent charge of high-weathered soil in this area may be related to retention/ release of SO_4^{2-}, resulting in temporary acidification of the stream water, since the soil pH was significantly higher in rainy season than in dry season. The N budget in the internal circulation was much larger than in external budget. An input from Ao layer to mineral soil surface and a supply with mineralization or nitrification may assimilate mostly into the vegetation because the leaching from the soil was very few in comparison with input and supply.

(4) Prediction of acidic substances emission based on the population dynamics and economic changes

Changes in consumption of cereals and livestock products up to 2030 in China were predicted based on the various kinds of statistics including meat production, feed supply for animals, household consumption of meat etc. Recent trend of world food trade was investigated to create the scenario of future supply of animal feed in China. Then the amount of the nitrogen load generated from food production and supply in China was estimated, which was proved to be one of the major emitters of reactive nitrogen in East Asia.

The statistical data in China had large uncertainty and were inconsistent with each other. Compromising the inconsistency, production amount of livestock products was revised, which was about 70% of the statistics in 2005. Per capita food consumptions in urban and rural area

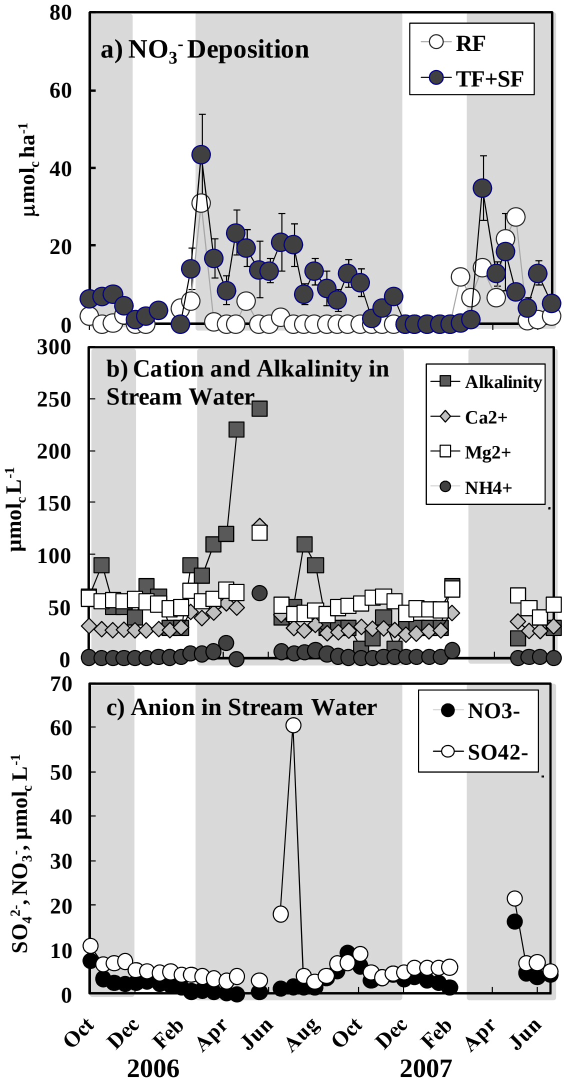

Fig. 3 Seasonal changes in nitrate deposition and in stream water chemistry (Shadow parts represent rainy season.)

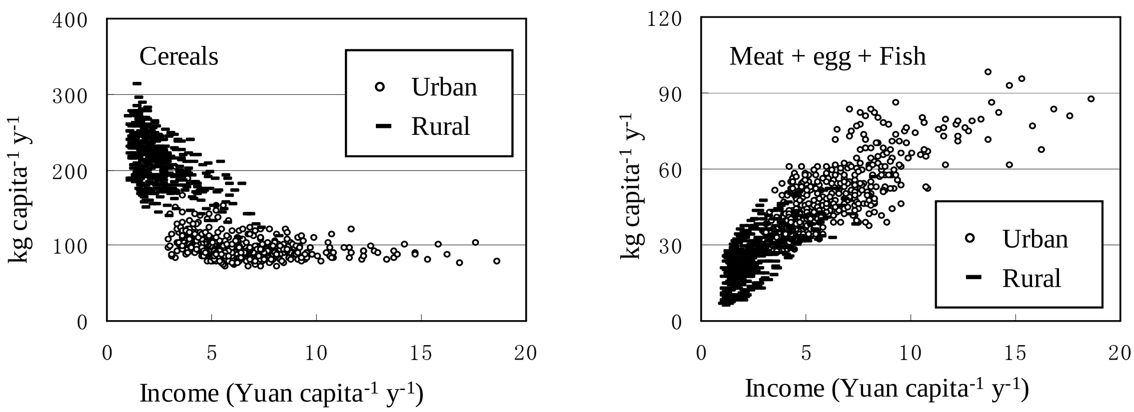

Fig. 4 Relationship between per capita food consumption and income based on the data from 1992 to 2005 in each province in China

were strongly related with income (Fig. 4). Based on this relationship, the scenario that newly demanded feed will be imported as soybean meal, population growth predicted by United Nation and population immigration model from rural to urban area, nitrogen load from agriculture, livestock waste and human waste were predicted. The resulted values in 2030 were 1.2, 1.6 and 1.1 times of the values in 2005.

(5) Development of a model estimating the changes in material cycle at the East Asian scale

Ammonia emission due to agriculture was evaluated for nine countries in East Asia from 1980 to 2030 based on the amount of livestock waste estimated by the method described in the previous section and nitrogen fertilizer consumption, and spatial distribution of atmospheric deposition of ammoniacal substances at the 8 km×8 km grid by using the land use distribution and a simple deposition model. A nitrogen cycle model for forest ecosystems was made for large scale estimation of nitrogen concentration in stream water based on the estimated atmospheric nitrogen deposition.

Ammonia emission in East Asia in 2000 was estimated to be 6.68 million tN, which was about 1.5 times of NOx emission. Spatial distribution of ammoniacal substances deposition was roughly related with the measurements in our study sites and EANET sites. Ammonia emission was predicted to become twice in 2030 when food trade ratio to demand was assumed to be similar with the present value. Nitrogen cycle model was applied to Japanese forested catchments to validate the model and then it was applied to the East Asian area. Nitrogen concentration in stream water was estimated to increase along the east coast of China, around the lower leach of the Changjiang River, and Viet Nam in the next 10 to 20 years (Fig. 5).

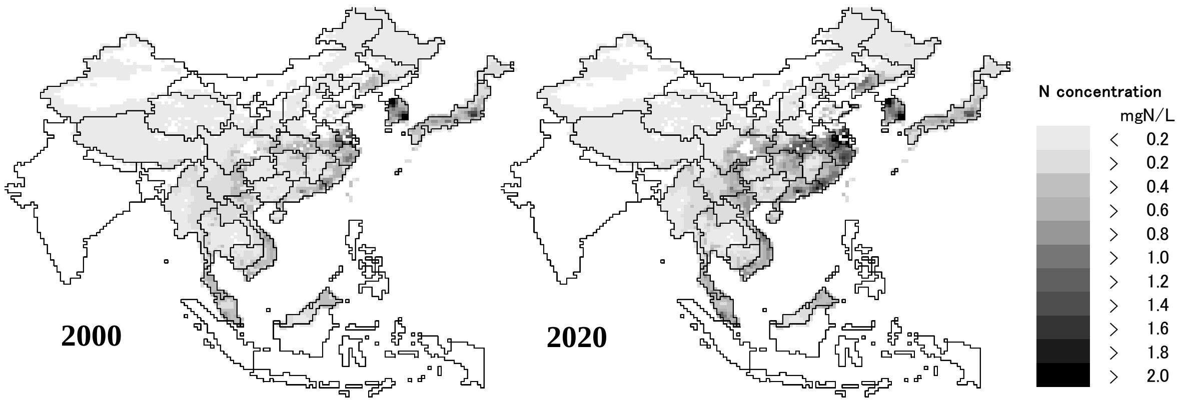

Fig. 5 Estimated and predicted distribution of nitrogen concentration in stream water.
(White areas are outside the study area)

4 . Discussion

Field measurements were carried out in areas with different meteorological conditions, different soil and vegetation types: from sub-boreal to sub-tropical forest in East Asia. Atmospheric deposition amounts and soil and stream water chemistry had very wide range and the behavior of acidic substances and other elements in the soil and exporting process from soil layer to stream water were different from site to site depending on the unique property of soils and meteorology. Despite these differences, however, nitrogen concentration in stream water, soil and litter were shown to relate with the atmospheric nitrogen deposition in rainfall (Fig. 6), suggesting the chronic

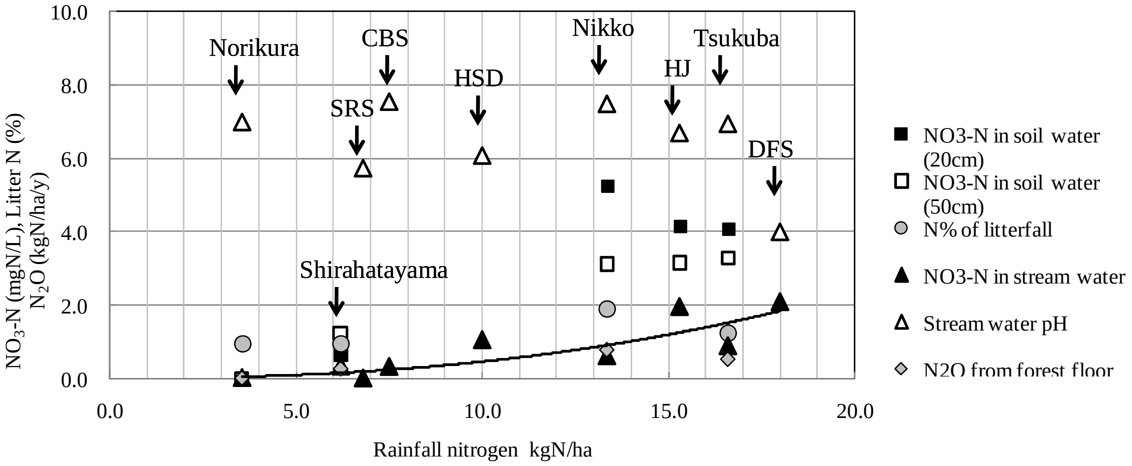

Fig. 6 Relationship between nitrogen deposition and nitrogen concentration in ecosystem components

nitrogen deposition may affect the nitrogen status in ecosystems after a long time.

China is the most important country when we consider the effect of nitrogen deposition. Food production was considered to be the major factor to determine the future nitrogen deposition and realistic prediction is desirable. However various uncertainties exist in the estimation mainly caused by uncertain statistical data. Some processes such as compromising the inconsistency among the statistics should be necessary. Estimation of ammonia emission also has uncertainty. Production amounts of livestock products were used as the base data in the estimation. This method tends to underestimate in the developing counties while the conventional method based on emission rate per head was considered to have a tendency to overestimate. Parameters suitable for Asian condition should be derived for more accurate estimation.

References

1) Galloway J.N., Nitrogen mobilization in Asia. Nutrient Cycling in Agroecosystems, 57, 1–12 (2000).

2) Aber, J. et al., Nitrogen saturation in temperate forest ecosystems hypotheses revisited. BioScience 48, 921-934 (1998)

Major Publications

1) J. Shindo, K. Okamoto, and H. Kawashima：Ecological Modelling, 193, 703-720 (2006) “Prediction of the environmental effects of excess nitrogen caused by increasing food demand with rapid economic growth in eastern Asian countries, 1961–2020”

2) K. Suzuki, T. Kumamoto, M. Tanaka, M. Muramoto and M. Namba: Journal of Japanese

Association of Hydrological Science 36, 105-116 (2006)
"Hydrologic cycle in a mountainous catchment" (in Japanese)

3) H. Toda, M. Shiina, M. Yamazaki, M. Kanno and K. Imai: Journal of Japanese Association of Hydrological Science 36, 117-122 (2006)
"Human impact on nitrogen concentration of streams and rivers in Nagano Prefecture" (in Japanese)

4) M. Honda, J. Shindo, K. Okamoto and H. Kawashima: Poster paper at the International Association of Agricultural Economists Conference, http://agecon.lib.umn.edu/cgi-bin/pdf_view.pl?paperid=22207&ftype=.pdf, 1-16 (2006)
"Increase of Residential Electricity Consumption in Urban and Rural China by province"

5) M. K. Koshikawa, T. Takamatsu, S. Nohara, H. Shibata, X. Xu, M. Yoh, M. Watanabe and K. Satake： Applied Geochemistry 22, 1209-1216 (2007)
"Speciation of aluminum in circumneutral Japanese stream waters"

6) Wuyunna, K.Okamoto and H.Kawashima : International Journal of Ecodynamics,2,2, 97-107(2007)
"Analysis of vegetative biomass changes in steppes of Inner Mongolia, China, using multitemporal Landsat, climatic and socioeconomic data"

7) H. Sase, A. Takahashi, M. Sato, H. Kobayashi, M. Nakata, and T. Totsuka: Environmental Pollution 152, 1-10 (2008)
"Seasonal variation in the atmospheric deposition of inorganic constituents and canopy interactions in a Japanese cedar forest"

8) W. Hamaguchi, K. Okamoto, J. Shindo and H. Kawashima: Journal of Environmental Science, 21, 143-152 (2008)
"The environmental pollution prolonged by Asian-style development: In case of Dianchi Lake, Yunnan Province, China"

9) M. Kamisako, H. Sase, T. Matsui, H. Suzuki, A. Takahashi, T. Oida, M. Nakata, T. Totsuka, and H. Ueda: Water, Air, & Soil Pollution (2008)
"Seasonal and annual fluxes of inorganic constituents in a small catchment of a Japanese cedar forest near the Sea of Japan" (in press)
"Seasonal variation in the atmospheric deposition of inorganic constituents and canopy interactions in a Japanese cedar forest"

10) M. Kamisako, H. Sase, T. Matsui, H. Suzuki, A. Takahashi, T. Oida, M. Nakata, T. Totsuka, and H. Ueda: Water, Air, & Soil Pollution (2008)
"Seasonal and annual fluxes of inorganic constituents in a small catchment of a Japanese cedar forest near the Sea of Japan" (in press)