Integrated Monitoring Program on Acidification of Chinese Terrestrial Systems IMPACTS

Annual Report - Results 2003

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Preface

The first Sino-Norwegian collaboration on acid rain in China was established between the Research Center of Eco-Environmental Sciences and the University of Oslo in 1988, with monitoring activities in the Guiyang area. In 1997, prior to the IMPACTS-project, several acid rain experts from Norway and China visited a range of sites located in the Chinese acid rain control zone. The purpose was to establish contacts between Norwegian and Chinese experts within the field of acid rain research and monitoring. China already had a network of air pollution monitoring stations in urban areas, but few sites in rural and sub-urban areas. The need for such monitoring sites was emphasised. Previous research in Europe and North-America had shown that rural and sub-urban areas, located far from emission sources, may receive significant amounts of acidifying compounds due to long range transport.

The IMPACTS project was launched late 1999 as a five-year collaboration project between China and Norway. In the IMPACTS project an integrated monitoring program was designed to monitor meteorology, air quality, the chemistry of precipitation, soil, soil water, surface water, as well as forest health and biodiversity of ground vegetation at a limited number of sites. This integrated monitoring concept allows an assessment of air pollution damage to terrestrial ecosystems in China. IMPACTS represents a cost-effective way of monitoring integrated parameters observed and measured by different scientific disciplines at selected sites. The IMPACTS project is funded by the Norwegian government (30 million NOK, ≈ 30 million RMB) and different Chinese sources (SEPA, local EPBs, MOST).

The IMPACTS sites are unique in the world with respect to the level of integration of different scientific disciplines and they have the potential to become China's key sites for monitoring effects of airborne pollutants on terrestrial ecosystems. We believe that data from the sites will prove to be extremely valuable for the Chinese authorities in their work for future national and international emission reduction protocols. In the IMPACTS project, specific field and laboratory manuals for each location have been prepared, in line with international standards. Manuals in both Chinese and English are available for field site monitoring, laboratory analysis, forest monitoring and ground vegetation monitoring. In addition, a chemical laboratory quality control handbook and an integrated electronic workbook (in Excel) for quality control and monthly data reporting are available. In the present report, the main focus is on presenting last year's results. For details regarding methods, sampling, sites, quality control etc., reference is made to the manuals.

The Chinese Research Academy of Environmental Sciences (CRAES) and the Norwegian Institute for Water Research (NIVA) have had the technical responsibility for the IMPACTS-project. Totally 13 Chinese and seven Norwegian institutes participate. The project includes five monitoring sites; two sites in the Guizhou province, and one site in each of the Chongqing, Hunan and Guangdong provinces. The responsibility for the daily management of the sites, including field and laboratory work, is at the local level in close collaboration with central Chinese institutes in Beijing.

On behalf of the IMPACTS group we want to thank the Norwegian and Chinese governments who have made this project possible. We sincerely believe that this project is of great benefit to China and the Chinese environment, as well as it is a positive contribution to the collaboration between the two countries.

Beijing November, 2004

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Summary

Sulphur deposition is high at all IMPACTS sites and exceeds maximum levels observed in Europe and North-America. Total sulphur deposition at the IMPACTS sites in 2003 ranged from 1.8 to 16 g S m^{-2}. The contribution from dry deposition is considerable; the dry deposition is often larger than the wet deposition. The IMPACTS data, in particular those from the remote Lei Gong Shan site (LGS), clearly document long-range transport of air pollutants. Due to the actual and expected future energy consumption and emission strategy in China, the long-range transport of air pollutants may significantly increase with subsequent increased environmental damage in rural and remote areas in China. The deposition monitoring shows increased sulphur wet deposition at all sites from 2002 to 2003, which agrees with the increase reported for sulphur emissions.

In addition to sulphur deposition, depositions of reactive nitrogen (nitrate and ammonia) and calcium are also significant at the IMPACTS sites, which clearly demonstrates that pH alone is not a good indicator for acid deposition. Total nitrogen deposition in 2003 ranged from 0.6 to 4.4 g N m^{-2}. The calcium deposition ranged from 1.8 to 12 g m^{-2}.

High concentrations of ground level ozone, above critical levels for vegetation and forest, have been observed at the Liu Xi He site (LXH) in Guangdong province.

Soil acidification gives rise to high concentrations of toxic aluminium in soil water at several sites. At the Tie Shan Ping site (TSP) in Chongqing aluminium occurs at a level where long-term harmful effects on trees might be expected. Defoliation and mortality of trees have been severe. Insect attacks are apparently a major cause of the forest damage. However, this leaves the possibility of predisposing effects from air pollution as a key question for further studies. Defoliation has been considerable also in the Liu Chong Guan site (LGS) in Guiyang, especially in 2003. The other three catchments had minor defoliation only. High foliar nitrogen concentrations have been measured in the Cai Jia Tang site (CJT) in Hunan and in particular at LGS in Guizhou. Although foliar phosphorous concentrations are not particularly low, the high N values result in low P/N-ratios. Possible effects of air pollution and soil acidification on forest health remain uncertain, and could include interactions with other stress factors.

The first reanalyses of ground vegetation in the LCG, TSP, LGS and CJT sites were performed only two years after establishment analyses. Significant changes in ground vegetation and plant biodiversity changes were found. The results could not be explained by acid deposition but it was clearly shown that bryophytes are good indicators of biotic effects of short term climate fluctuations. Experiences from other parts of the world show that vascular plants are good indicators for identifying long-term effects of acid rain and soil acidification. However, data from longer time periods are needed to identify vegetation changes that may be related to soil acidification or direct effects of air pollutants.

Modelling results suggest that the currently planned 20% reduction in sulphur emissions is far from sufficient to avoid further soil and water acidification. This was shown for the Tie Shan Ping site in the 2002 report and calculations for the Lei Gong Shan site presented in this report give the same conclusion. As more data are generated, dose-response relationships, critical load estimates and model predictions will obviously be improved.

1. Major findings/ extended abstract

1.1 General conclusions

Sulphur deposition is high at all IMPACTS sites, which confirms the results from the Chinese national air quality monitoring program. In contrast to most of the national monitoring sites,located in or near cities and primarily measuring air pollution from local sources, IMPACTS sites are located away from cities in forested areas. The IMPACTS data clearly show long-range transport of air pollutants. This is well documented by the relatively high deposition of sulphur even at the remote LGS site. Because the relationship between emissions and the deposition of air pollutants is not necessarily linear, it is important to have a network of stations both in urban and rural areas to reveal if reductions in emissions cause equal reduction in deposition. Furthermore, since dry deposition of air pollutants is of significant importance, both dry and wet deposition have to be estimated in order to assess the total deposition of pollutants. Dry deposition may be estimated indirectly by throughfall measurements.

Impacts from acid deposition are only partly caused by sulphuric acid (H_2SO_4). Also nitric acid (HNO_3) is important and will likely be even more important in the coming years. Deposition of calcium and ammonia (NH_3) are also of great importance, since these compounds may neutralise the acids in precipitation. Even though ammonia neutralises acidity in precipitation, the resulting ammonium (NH_4^+) contributes to acidification of soil- and surface water through chemical processes in the soil. This clearly demonstrates that pH alone is not a good indicator for acid rain, particularly in areas with high deposition rates of ammonia. This should be considered when deciding the target area for acid rain control. Furthermore, emission and deposition of sulphur, nitrogen and calcium should all be included and integrated in future plans for acid deposition abatement. Since ammonium and nitrate are also important for eutrophication of terrestrial and aquatic ecosystems, monitoring of these compounds and their environmental effects will serve more purposes than acidification only.

Atmospheric sulphur is mainly derived from combustion of fossil fuels, primarily coal. Ammonia primarily derives from agricultural activities (life stock and fertilised cropland, e.g. paddy fields), whereas nitrate primarily derives from combustion for example in power plants, vehicles and ships. Sources of Ca-rich particles are both natural (deserts) and man-made (combustion, construction, land use).

Ozone (O_3) may contribute to forest and vegetation damage as well as reduced crop production. The O_3 levels in Liu Xi He indicate exceedance of critical levels for crops and forests in this area. So far, no exceedance has been documented at the other sites. Since nitrogen oxides contribute to formation of ozone, and nitrogen oxide emissions are expected to increase in the future, O_3 concentrations are likely to increase in large areas of China. Thus monitoring of O_3 deserves particular attention.

At Tie Shan Ping, the defoliation of dominant Masson pine (*Pinus massoniana*) has been considerable (40-50%) during the four years of monitoring (2000-2003), accompanied by high mortality among defoliated trees in 2001. At Liu Chong Guan, the defoliation of dominant Masson pine (*Pinus massoniana*) has increased during the four monitoring years (2000-2003) with an especially large increase in 2003. Analyses of foliar chemistry do not show clear deficiencies for the studied nutrients, however, some imbalances are found, and these need to be followed up. The causes of defoliation, mortality and nutrient imbalances are uncertain. Insects and summer drought are candidates to explain variations in tree health/defoliation. Acidification of soil mobilises toxic aluminium, with possible harmful effects on trees. Calcium and magnesium are believed to play an important role in modifying aluminium toxicity. The high molar ratio between aluminium and (calcium + magnesium), and the relatively high aluminium concentration in soil water in Tie Shan Ping may therefore have weakened the forest health, although insect attacks were found to be the direct cause. The aluminium/(calcium +

magnesium) ratios are also high in some soil horizons in Liu Xi He, indicating possible negative effects on trees.

Investigations of the ground vegetation recorded 147 species at Tie Shan Ping, 171 species at Liu Chong Guan, 285 species at Lei Gong Shan, 127 species at Cai Jia Tang, and 154 species at Liu Xi He (first year data only). Reanalyses after two years of ground vegetation monitoring revealed changes in plant biodiversity, single species abundances, and species composition. The number of bryophytes (mosses) decreased in LCG and TSP and increased in LGS and CJT. The decrease in bryophyte numbers in LCG and TSP were probably due to much drier weather conditions in the reanalysis year (2002) compared to the first year (2000). The increase in bryophyte numbers in LGS and CJT were probably due to more moist weather conditions during the reanalyses year (2003) compared to the first year (2001). These results were in agreement with the results from the Norwegian ground vegetation monitoring that bryophytes are good indicators of biotic effects of climatic fluctuations. Experiences from other parts of the world show that vascular plants are good indicators for identifying long-term effects of acid rain and soil acidification, but data from longer time periods are needed to identify vegetation changes that may be related to soil acidification or direct effects of air pollutants.

Possible effects of future atmpospheric deposition have been modelled for TSP, LGS and CJT using various deposition scenarios. One deposition scenario included a 20% reduction in SO_2 emissions which is the target in the 10th 5-year plan. Although the modelling exercises illustrated that the soil processes are not fully understood, the results strongly suggested that considerably greater reductions in SO_2 emissions are needed in order to avoid negative effects due to acidification at TSP and LGS, whereas a 20% reduction may be sufficient to achieve stabilization in soil base cation status at the selected plot for CJT.

1.2 Overall results per site

Tie Shan Ping (TSP)
High mountains surround Chongqing City, which causes poor air circulation and thus high accumulation of air pollutants. Accordingly the Tie Shan Ping site, located in the hills about 25 km northeast of the city, receives high deposition of sulphur, calcium and reactive nitrogen. The deposition is the highest among the monitoring sites. Sulphate is the dominant anion and calcium the dominant cation in precipitation, soil water and surface water. The high deposition of ammonium is partly assimilated by the vegetation and partly nitrified in the soil to nitric acid. Soil acidification, resulting from sulphuric and nitric acid, causes elevated concentrations of aluminium in soil water. The surface water is acidified (pH < 5.0). Reduced forest health is documented.

Liu Chong Guan (LCG)
Mountains surrounding Guiyang City cause poor air circulation and high accumulation of air pollutants. The catchment is a suburban site located close to large emission sources resulting in high deposition of sulphur as well as alkaline dust. By contrast to the Tie Shan Ping and Cai Jia Tang sites the deposition of nitrogen is rather low. Sulphate and calcium dominate precipitation, soil water and surface water. Due to low deposition rate the concentration of nitrate is low in soil and surface water. The surface water is acidified (pH < 5.0). Reanalyses of vegetation document significant changes which are likely to be caused by short-term variation in climate annual variations in precipitation.

Lei Gong Shan (LGS)
This is a remote site with no large, local emission sources. However, the relatively high wet deposition of sulphur and nitrogen illustrates the importance of long range transported air pollutants. As yet, the catchment is not significantly acidified, even though the low conductivity in surface water indicates an area relatively sensitive to acidification. So far, neither significant acidification of surface water (pH > 6.0) nor effects on forest health have been observed.

Cai Jia Tang (CJT)
The site has relatively high deposition of both sulphur and nitrogen, but also high inputs of alkaline dust. Since the base saturation in the soil is relatively high, water acidification is not to be expected. However, high acid loading and intensive leaching of bases may cause acidification of the surface soil in the medium-long term. Calcium and sulphate predominate in soil water and surface water. The deposited nitrogen is largely assimilated by the vegetation and net nitrification to nitric acid is modest. Neither significant acidification of surface water (pH > 6.0) nor effects on forest health have been observed.

Liu Xi He (LXH)
The site receives medium deposition of nitrogen and sulphur, and relatively low inputs of alkaline dust compared with the other sites. Since Liu Xi He is located relatively close to the sea, the catchment receives much more sodium and chloride from marine aerosols than the other sites. Despite relatively low acid load, the ratio of aluminium to (calcium + magnesium) in the soil is high. The low ionic strength of surface water indicates that the catchment is sensitive to acidification, even though no strong indications of acidification are documented at present. The ground-level ozone concentrations measured are relatively high, but so far no effects on forest health have been observed.

Table 1. Total deposition of sulphur (S), nitrogen (N) and calcium (Ca) at the IMPACTS monitoring sites in 2003. All values in gram per square meter (g m^{-2})

	S	N	Ca
Tie Shan Ping (TSP), Chongqing	16	4.1	12
Liu Chong Guan (LCG), Guizhou	4.2	0.6	3.3
Lei Gong Shan (LGS), Guizhou	1.8	1.1	1.8
Cai Jia Tang (CJT), Hunan	7.9	4.4	7.6
Liu Xi He (LXH), Guangdong	4.5	1.3	2.2

2. Introduction

2.1 Background

Without countermeasures economic growth is generally accompanied by increasing environmental problems. One major cause is the close link between economic growth and energy consumption. In China, coal accounts for about 70% of the commercial energy production, and it is likely that coal will be the major energy carrier also in the coming decades. This leads to large emissions of SO_2, the most important precursor of acid rain. Economic growth also leads to increasing numbers of vehicles emitting large amounts of nitrogen oxides (NOx), another important precursor of acid rain.

Acid rain was recognised as a potential environmental problem in China in the late 1970s. In 1998, SEPA estimated that ≈ 800 000 km^{-2}, or 8.4 percent of the country was affected by acid rain. The economic loss due to negative effects of acid rain on human health, crops and trees were estimated at 13.25 billion US$. Although such estimates are highly uncertain, it is beyond doubt that China is facing major problems due to acidification, of an equal or maybe larger magnitude as compared to those experienced in Europe and North America.

Due to the large negative effects of air pollution in urban environments, China has primarily focused on improving air quality in these areas. The main strategy has been to remove emissions in the cities. As more emissions sources are moved to sub-urban areas, and as most air pollutants have the potential to be transported far away from the emission sources, negative effects of air pollution will be increasingly seen in suburban and rural areas,. This means increasing impacts of acid deposition on natural ecosystems. The main objective of the IMPACTS project is to establish integrated monitoring sites in sub-urban and rural terrestrial Chinese ecosystems to study effects on air pollution on forest, vegetation, soil, soil water and surface water.

In the process of formulating a Chinese policy on acid rain, the Chinese authorities have been drawing on the lessons learned in dealing with acid rain problems in Europe, in particular the experiences from establishing *The Convention on Long-range Transboundary Air Pollution* under UN-ECE in 1979. This agreement was reached after scientists undisputedly were able to demonstrate the link between sulphur emissions in continental Europe and the acidification of Scandinavian lakes. Studies confirmed that air pollutants could travel many hundred kilometres before deposition and damage occurred. This implies that co-operation at international level is necessary to solve problems such as acidification.

Chinese research projects and government studies have provided much information needed for implementing adequate control measures. However, there are still large gaps in the scientific knowledge about air pollution effects in China, particularly regarding quantification of effects. In order to provide a sound scientific basis for cost-effective control measures to reduce emissions of acidifying substances, SEPA has found it beneficial to exploit foreign experience and expertise, methodologies and "state of the art" equipment. Since Norway has considerable experience and competence in acid rain research, and Norwegian research institutions play key roles in European co-operation on acid rain, Norway was the first country China asked to support its work on acid rain. The Sino-Norwegian IMPACTS project is a direct consequence of this initiative, and a cornerstone in China’s international co-operation on acidification.

2.2 The monitoring program

The monitoring program is established in accordance with international standards at five sites in four provinces. Detailed manuals for the monitoring activities have been written and are available in

Chinese and English. For details on site descriptions and sampling methodologies the reader is referred to these publications. The monitoring at the sites is highly integrated, including monitoring of air quality, meteorology, deposition, soil, soil solution, surface water, forest health and biodiversity of ground vegetation.

Data from all parts of the monitoring program are reported here. Data are reported using abbreviations for the different samples collected:

- Air concentrations: SO_2, NO_2, O_3, composition of particles, nitric acid + nitrate in particles
- Main meteorology
- Deposition: wet only (WO), bulk (BD), throughfall collected below the tree canopy (CTF) and below the ground vegetation (FTF).
- Soil solution chemistry from several depths in the soils (L0-L4, increasing number at increasing soil depth).
- Soil temperature and moisture
- Water chemistry and discharge
- Litterfall amount and chemistry
- Needle chemistry
- Tree growth and vitality parameters
- Ground vegetation

2.3 The intercomparison programs

An important task of the IMPACTS project is the establishment of high quality laboratories, focusing on laboratory capacity, instrument quality, analytical methods and quality assurance. Consequently, the laboratories participate in both internal and international intercomparison networks for surface water (ICP-Waters) and precipitation (EMEP). In addition the laboratory used for soil analysis is involved in intercomparison tests with other laboratories.

2.4 Description of the monitoring sites

The monitoring sites are located in South and Southwest China (Figure 1) and belong to the defined acid rain control zone. The area has a monsoonal climate with dry winters and wet summers. Prevailing wind direction is from the northeast in the winter and from the southwest in the summer. Relative air humidity varies around 80%.

At all sites, except Liu Xi He, the parent material of the soil is sedimentary bedrock, such as sandstone and shale. At Liu Xi He granite predominates. In the regions with sedimentary bedrock, the geology is highly inhomogeneous with limestone in the vicinity of the watersheds.

Two soil types predominate, i.e. yellow soil and red soil according to the Chinese classification system. These soil types are similar to Haplic Alisol and Acrisol according to the FAO (Food and Agriculture Organisation of the United Nations) classification system. These soils are representative for this part of China and probably sensitive to acidification (Table 2).

All sites are forested and practically undisturbed by present land-use activities. The forests are mixed deciduous and coniferous forests dominated by Masson pine (*Pinus massoniana*) and Chinese fir (*Cunninghamia lanceolata*). Much of the forests were planted in the 1960s after intensive logging during "the Great Leap Forward" (1958-1962).

Sulphur dioxide (SO_2) and sulphuric acid (H_2SO_4) are important compounds in dry and wet deposition, while nitrogen oxides (NO_x) and nitric acid (HNO_3) are of increasing importance (Table 2) The deposition also contains significant amounts of ammonium (NH_4) calcium (Ca) and magnesium (Mg).

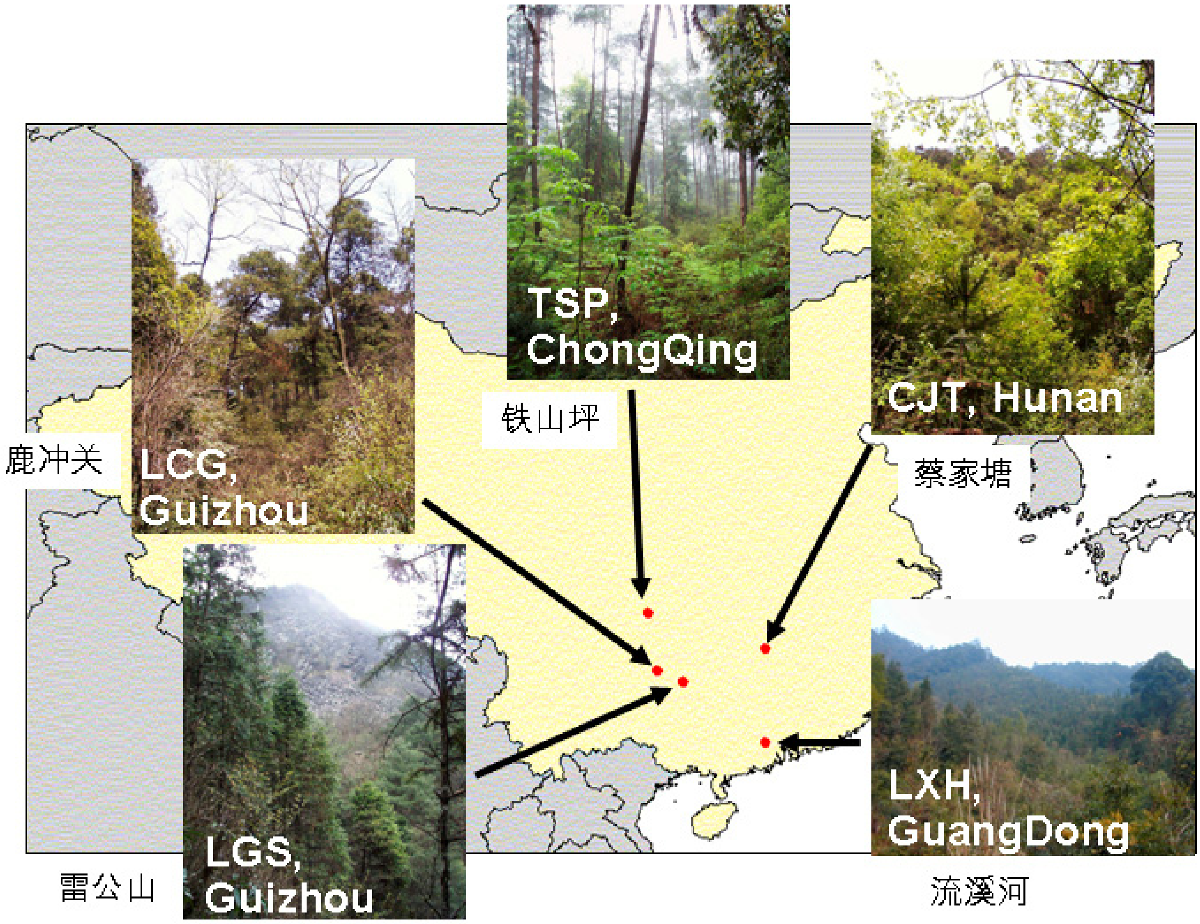

Figure 1. Location of the IMPACTS monitoring sites.

2.4.1 Tie Shan Ping

Tie Shan Ping (TSP) is located in the Sichuan basin about 25 km north-east from the centre of Chongqing City (104°41'E, 29°38'N, Figure 1). The TSP catchment (Appendix C) is part of a national protected forest area. The catchment area is about 16 ha and the elevation ranges from 450 to 500 m a.s.l. TSP has a subtropical, humid climate with little frost and snow, but much fog all year round. Annual mean temperature and precipitation (1971 – 2000) at Sha Ping Ba outside of Chongqing is 18.2°C and 1105 mm, respectively.

2.4.2 Liu Chong Guan

Liu Chong Guan (LCG) is located in Guizhou province (106°43`E, 26°38`N) about 10 km north-east of Guiyang City (Figure 1). The LCG catchment (Appendix C) is part of a protected area in a botanical garden. The catchment (Appendix C) is about 7 ha and the elevation ranges from 1320 to 1400 m a.s.l. Annual mean temperature and precipitation (1971 – 2000) in Guiyang is 15.3ºC and 1118 mm, respectively. The city has an average of 220 cloudy days per year (Zhao et al., 1988).

Table 2. Catchment area, annual amount of precipitation, estimated total deposition of sulphur (S), nitrogen (N) and calcium (Ca), and pH, base saturation (BS) and carbon/nitrogen ratio (C/N) in soils at

the five catchments in 2003, i.e. Tie Shan Ping (TSP), Liu Chong Guan (LCG), Lei Gong Shan (LGS), Cai Jia Tang (CJT) and Liu Xi He (LXH).

Site	Area	Total deposition[1]				Soil quality				
		amount	S	N	Ca	Bedrock	Hor-izon	Soil pH	BS	C/N
	ha	mm	$g\ m^{-2}\ yr^{-1}$						%	
TSP	16.3	1168[2]	16.0	4.1	12	Sandstone	A	3.5	26	20
							B	3.8	9	12
LCG	6.8	621[2]	4.2	0.6[4]	3.3	Sandstone	A	3.6	33	19
							B	4.0	14	16
LGS	6.0	1367[2]	1.8	1.1[4]	1.8	Shale	A	3.9	46	15
							B	4.3	31	11
CJT	4.2	1196[3]	7.9	4.4	7.6	Sandstone/ shale	A	3.8	38	18
							B	4.0	16	12
LXH	261	1620[2]	4.5	1.3	2.2	Granite	A	4.0	17	21
							B	4.1	9	16

[1] Total deposition flux is based on forest floor throughfall (FTF) measurements. In cases where FTF deposition was smaller than the wet deposition, wet deposition is given aas the estimate for total deposition (marked as [4]).
[2] Bulk precipitation
[3] Wet only precipitation
[4] Based on wet deposition

2.4.3 Lei Gong Shan

Lei Gong Shan (LGS) is located in Guizhou province (108°11'E, 26°22'N), outside Lei Shan, a small mountain village 40 km south-east of Kaili City and 140 km east of Guiyang (Figure 1). The catchment (Appendix C) is part of a nationally protected mountain area with little human activity. The catchment area is about 6 ha and the elevation ranges from 1630 m to 1735 m a.s.l. Annual mean (1971 – 2000) temperature and precipitation at Kaili are 15.7°C and 1225 mm, respectively. However, note that Kaili is at a considerably lower altitude than the catchment at Lei Gong Shan. Fog is common, e.g. 315 foggy days were recorded in 1987. Only two mountain areas in China have more fog than Lei Gong Shan.

2.4.4 Cai Jia Tang

Cai Jia Tang (CJT) is located in Hunan province (112º 26'E, 27º 55'N). The catchment is on the southern side of the Cai Jia Tang mountain (Figure 1), 10 km west of the small city Shaoshan, the birthplace of Mao Zedong, 130 km south-west of Changsha City. The catchment area (Appendix C) is about 4.2 ha and the elevation of the site is from 450 to 500 m a.s.l. Annual mean temperature and precipitation (1987 – 2000) at ZhuZhou, close to the site, are 17.5°C and 1524 mm, respectively.

2.4.5 Liu Xi He

Liu Xi He (LXH) is located in Guangdong province (133°35'E, 23°33'N), 67 km north-east of Conghua City (Figure 1). LXH has a broad leaf evergreen forest. The catchment area (Appendix C) is about 261 ha and the elevation is about 500 m a.s.l. Annual mean temperature and precipitation (1987 – 2000) in Guangzhou, are 22.0°C and 1736 mm, respectively. The LXH site is a sub-catchment to a large drinking water reservoir, supplying Guangzhou with tap water. Both the bedrock (igneous plutonic granite) and the composition of soil are quite different from the other sites.

3. Results

3.1 Air concentrations

3.1.1 Main inorganic components

The annual average concentrations of the main components in air and aerosols are summarised in Table 3. The concentration levels are very different between the sites. The highest concentration of SO_2 is found in LCG, with an annual average of 42.7 µg S m^{-3} in 2003. LCG is located close to the severely polluted city of Guiyang. TSP, which is influenced by the emissions in Chongqing, also has a relatively high concentration of SO_2, 20.9 µg S m^{-3} in 2003. The lowest concentrations are found in LGS (only 0.55 µg S m^{-3} in 2003), which is the most remote site. The concentrations at LGS are comparable to background sites in Europe in contrast to the other 4 IMPACTS sites that have a much higher pollution level. At the sites with intensive measurements (TSP, CJT and LGS), the main component in airborne particles is $(NH_4)_2SO_4$, but in TSP and CJT $CaSO_4$ is also a considerable contributor. NH_4NO_3 is contribution as well in CJT and TSP but of less significance. Reduced nitrogen has a considerable higher concentration level than oxidised nitrogen; agricultural activity is clearly an important source.

The monthly average concentrations of the main species in air and aerosols are presented in Figure 2. At CJT the concentration varies with elevated concentrations during winter, but also some high episodes during summer, i.e. in July 2002. At LCG there was a clear seasonal variation with highest concentrations during the winter. In LXH there is seasonal variation with a tendency to with highest concentrations in winter, but also here high episodes of SO_2 were observed during summer as well. The same is true for TSP, the high episodes during summer can partly be explained by the dominant wind direction in this period, as the site is downwind from Chongqing in summer. At LGS there are some episodes but no clear tendency. The concentrations of gaseous nitric acid and ammonia, and of nitrate and ammonium in aerosol particles are determined by "filter-pack" sampling. This method makes separation of inorganic nitrogen species in gas and particles unreliable due to the volatile nature of ammonium nitrate. Therefore only the sums of nitric acid and nitrate, and of ammonium and ammonia are unbiased. However, since most of the ammonium is bound to sulphate this bias is probably quite small. It is obvious that both gaseous and particulate nitrogen are important in the total nitrogen deposition, Figure 2.

Table 3. Annual average air and aerosol concentrations

Site	Year	Air		Aerosol						air + aerosol	
		NO_2 µg-N/m^3	SO_2 µg-S/m^3	SO_4 µg-S/m^3	Cl µg/m^3	Na µg/m^3	K µg/m^3	Ca µg/m^3	Mg µg/m^3	sumNO3 µg-N/m^3	sumNH4 µg-N/m^3
TSP	2001*	3.65	16.98	5.59	0.71	0.49	1.50	3.73	0.52	1.65	5.33
	2002	5.62	18.38	7.24	0.84	0.41	2.69	3.80	0.53	2.05	7.80
	2003	5.37	20.16	7.92	0.93	0.95	3.08	3.63	0.33	2.27	7.00
LCG	2002	1.8	37.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	2003	-	42.7	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
LGS	2002*	0.58	2.59	1.30	1.10	0.08	0.20	0.25	0.04	0.16	1.71
	2003	-	0.55	1.43	0.52	0.05	0.17	0.25	0.03	0.11	1.16
CJT	2001*	2.49	9.55	6.12	0.39	0.52	1.92	2.22	0.29	1.82	5.19
	2002	2.02	9.37	7.48	0.49	0.59	2.47	2.58	0.31	1.75	5.67
	2003	2.39	10.77	5.46	0.29	0.31	1.67	1.67	0.15	1.81	5.94
LXH	2002	5.3	6.4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	2003	4.3	6.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

*2001, TSP Nov and december missing. CJT, measuremnts from 20th of march. 2002 LGS jan-march is missing, n.d. means not determined, - means too low data capture

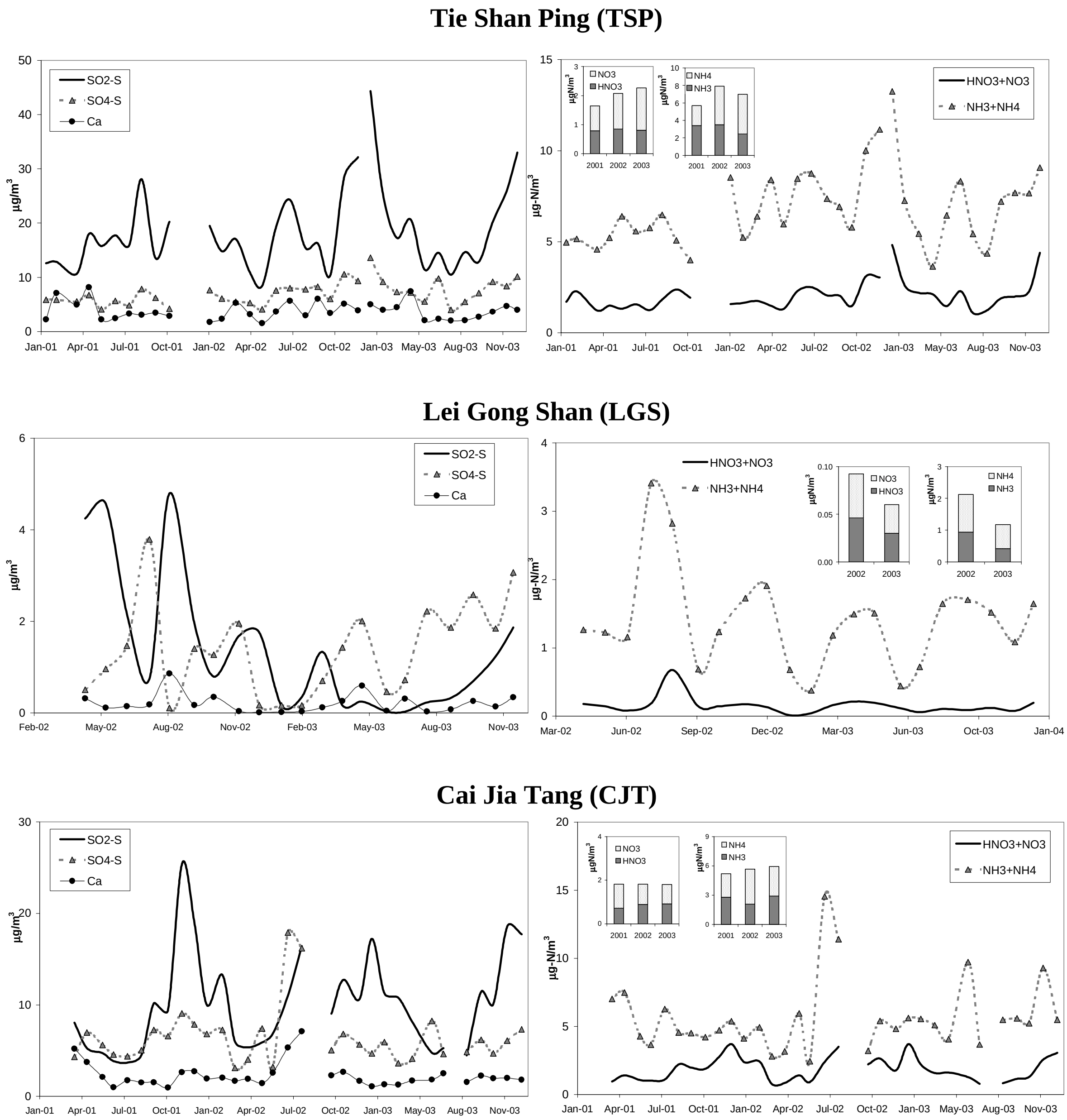

Figure 2. Monthly average air and aerosol concentrations at TSP, CJT and LGS, - sulphur dioxide and particulate sulphate and calcium (left) and sum of nitrate (nitric acid + nitrate in particles) and sum of ammonium (ammonia + ammonium) (right). The distribution between gas and particulate phase is shown in the boxes inside the nitrogen figures.

3.1.2 Ozone

High concentrations of ozone have adverse environmental effects such as impacts on human health, agricultural crops, forest and material. International organisations and authorities have therefore formulated critical levels of ozone. The critical levels defined by UN-ECE for protection of vegetation are 150 $\mu g/m^3$ for hourly mean, 60 $\mu g/m^3$ for 8 hours mean and 50 $\mu g/m^3$ for 7 hours averaged over the growing season (April to September). The critical level formulated by WHO for protection on health is 120 $\mu g/m^3$ for hourly mean. Under the Convention of LRTAP it is also recommended to use critical levels for ozone exposure based on accumulated exposure in ppb hours over a concentration threshold during the growing season[1], AOT40 (1 ppb ≈ 2 µg/m^3). For agricultural crops the critical levels set at 3000 ppb.h. calculated for daylight values for a three months period, May to July. The critical levels for forest is 10000 ppb.h calculated for daylight hours during a six months period from April to September.

The ozone concentrations were determined with a UV-fluorescence at all sites. In CJT there were technical problems and the measurements up to the end of 2003 are therefore not reported. The data capture at LCG and LGS were too small to calculate reliable averages and exposure estimates. Missing data in the measurements series may be critical, especially in summer. In calculating AOT40 a 85% data capture is required. The data capture in LXH is below 50% and it is therefore difficult to give reliable exposure estimates. However, the results indicate that the ozone level in LXH is significant.

In Figure 3, one can see a clear diurnal variation in TSP and LXH showing maximum in the afternoon and lowest values early morning. This is a common observation due to enhanced photochemical reactions during daytime. The seasonal variation of the ozone concentrations indicate a maximum in the summer (Figure 4). The concentration level in LXH is very high. However, the data capture is not very high at LXH and TSP making it difficult to get a consistent data series; to calculate monthly averages a data capture of at least 30% has been set.

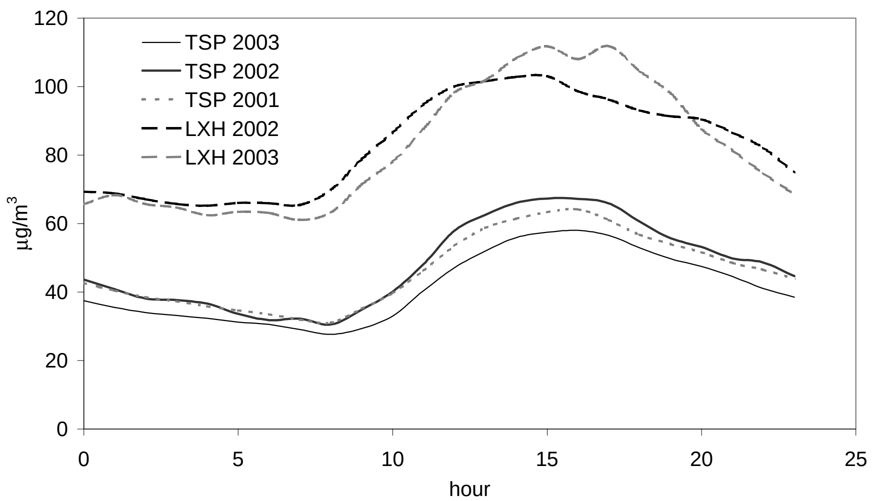

Figure 3. Diurnal variation for ozone concentration, averaged from April to September.

In Table 4 there is a summary of the data averages and exposure values from 2001 to 2003 given for TSP and partly for LXH; no calculations of AOT40 are done for LXH due to low data capture. At TSP the AOT levels are not exceeded, but there are a few days above 120 µg/m^3. At LXH on the other hand, measurements indicate that the critical levels for vegetation and forest are exceeded.

[1] AOT40: The sum of the differences between hourly ozone concentration and 40 ppb for each hour when the concentration exceeds 40 ppb during a relevant growing season.

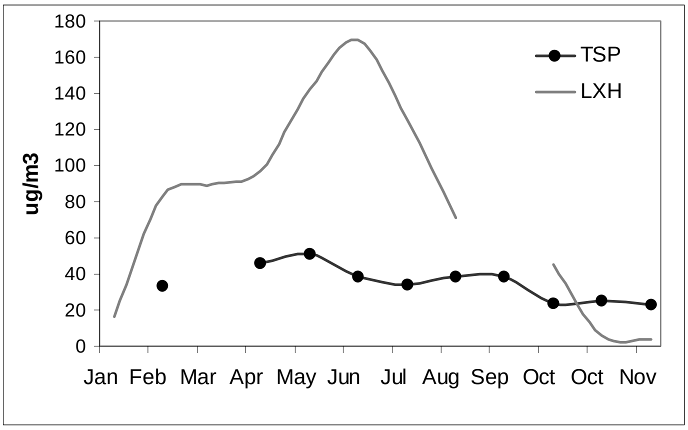

Figure 4. Monthly average concentrations of ozone in TSP and LXH in 2003, µg/m^3

Table 4. Ozone annual average, AOT40, number of hours and days exceeding 120 and 150 µg/m^3, and maximum concentrations.

	average	Data capture	AOT40 corr, ppb.h*		Total nr of data		>120µg/m$^{3\,a}$		>150µg/m$^{3\,a}$		Max	
	µg/m^3	per cent	May to Aug	Apr to Oct	hours	days	hours	days	hours	days	µg/m^3	date
LXH 2002	92.3	52	*	*	4524	213	1371	108	485	60	345	27.11
LXH 2003	77.1	-										
TSP 2001	40.6	71	1351	2401	6227	273	40	12	4	4	163	10.8
TSP 2002	40.9	83	1693	3420	7230	325	49	19	9	5	172	5. 8
TSP 2003	35.7	78	672	1318	6861	300	5	3	0	0	137	25.5

[a] Running 8 hours mean
* Corrected for data capture. The data capture is too low to give reliable exposure estimates

3.2 Deposition

3.2.1 Wet deposition

At all sites the predominant ions in precipitation are SO_4^{2-}, Ca^{2+} and NH_4^+. As for the air concentrations, the highest concentrations in precipitation are seen in LCG and TSP. The wet depositions of sulphur at these two sites in 2003 were 2.5 and 3.4 gS/m^2 at LCG and TSP respectively. The lowest depositions are observed in LXH and LGS with 2.1 and 1.6 gS/m^2 in the same year. The ammonium-N concentration is about twice as high as for nitrate-N at all sites. The total nitrogen in wet deposition is highest at CJT with 2.9 gN/m^2 and lowest at LCG with 0.6 gN/m^2 in 2003. Concentrations of all ions in precipitation for 2001, 2002 and 2003 can be found in Appendix B.

At LCG, TSP and LGS there are parallel deposition measurements using bulk and wet-only collectors. These should show comparable volumes, but the wet-only collector might underestimate the volume if it does not open immediately at the start of a rain event. This may happen e.g. after lightening, which causes a temporal shut down of the electricity at the site. At LGS and LCG there is a large difference between the two collectors in 2002 and 2003. Even though the bulk collector may collect the correct volume, it may overestimate the wet deposition of pollutants. This is because it may collect significant amounts of dry deposition (gases and particles) depending on the pollution level and sampling frequency,. Wet deposition has therefore been calculated using the precipitation amount from the bulk collector and the volume weighted averages from the wet-only collector.

Table 5. Annual wet deposition for sulphate, nitrate, ammonium and calcium, $gm^{-2}yr^{-1}$

		mm	SO_4-S	Ca	NH_4-N	NO_3-N
TSP	2003	1168	3.4	1.4	1.2	0.6
	2002	1558	3.9	1.3	1.6	0.7
	2001	959	3.1	1.1	1.2	0.5
LCG	2003	621	2.5	1.9	0.4	0.2
	2002	1080	3.5	2.8	0.8	0.3
	2001 [a]	407	1.2	0.9	0.3	0.1
LGS	2003	1367	1.6	0.7	0.6	0.5
	2002	2208	1.5	4.0[b]	0.9	0.4
	2001 [c]	1271	1.1	5.3[b]	0.3	0.1
CJT	2003	1196	3.0	0.8	1.8	0.9
	2002	1611	2.6	1.3	1.3	0.7
	2001 [d]	947	1.9	1.3	1.1	0.4
LXH	2003	1620	2.6	2.2	0.7	0.3
	2002	1253	1.2	1.5	0.4	0.5

a) The precipitation in LCG in 2001 does not include December.
b) The Ca deposition at LGS was probably overestimated in 2001 and 2002 due to analytical problems.
c) The precipitation in LGS in 2001 does not include January and December.
d) The precipitation amount at CJT in 2001 is underestimated because of overflow in the precipitation sampler

3.2.2 Total deposition

Total deposition of, S, N and Ca in 2001, 2002 and 2003 are presented in Figure 5, based on ground vegetation throughfall measurements (FTF). In 2003 the total deposition of sulphate ranges from 1.8 to 16 g S m^{-2} (or 115 to 1000 meq m^{-2}).

Total deposition is highly influenced by the dry deposition. Sulphate is enriched by a factor 4 at TSP while the total deposition is twice the wet deposition for the other sites (except LGS site). Ca is highly enriched in throughfall, e.g. at TSP where throughfall deposition is 8 times higher than wet deposition. Dry deposition of calcium-rich particles is very important for the total deposition. Nitrogen is about twice as high in the throughfall compared to the wet deposition, which means that the dry deposition is of the same magnitude as the wet deposition. This might be an underestimation because of the potential uptake of nitrogen in the tree crowns.

The total deposition of air pollutants consists of both wet- and dry depositions. Estimating the dry deposition is difficult. One approach is to use the gas- and aerosol concentrations and an estimated dry deposition velocity. However, this approach is uncertain because the magnitude of the dry deposition velocities for the different catchments is not known. There are only few studies of this and the deposition velocities used in the literature are probably not representative for Chinese forests. A more direct approach is to use the throughfall measurements. Gases and particles may deposit on the vegetation and this may be washed off by precipitation and collected by the throughfall collector. However, there is some uncertainty with this method as well because of the interaction with the canopy. The canopy may absorb some of the gases or particles, e.g. nitrogen, but it may also leach some elements, e.g. potassium (K). Sulphate and calcium are considered conservative i.e. having little interaction with the canopy, and throughfall probably gives a good estimate of the total deposition. In IMPACTS we have used two types of throughfall collectors, canopy throughfall (CTF) and ground vegetation throughfall (FTF) collectors. CTF is commonly used and is recommended for estimating the total deposition. As for CTF, FTF is affected by interactions with the tree canopy, but in addition

FTF is also affected by interactions with the ground vegetation. Therefore FTF usually has somewhat higher pollutant concentrations than CTF. The ground vegetation in the catchments is quite significant and dry deposition on this vegetation may contribute significantly to the total deposition. Also because measurement of CTF are lacking for some sites in 2001, we have chosen to use FTF fluxes as an estimate of the total deposition of S, N and Ca.

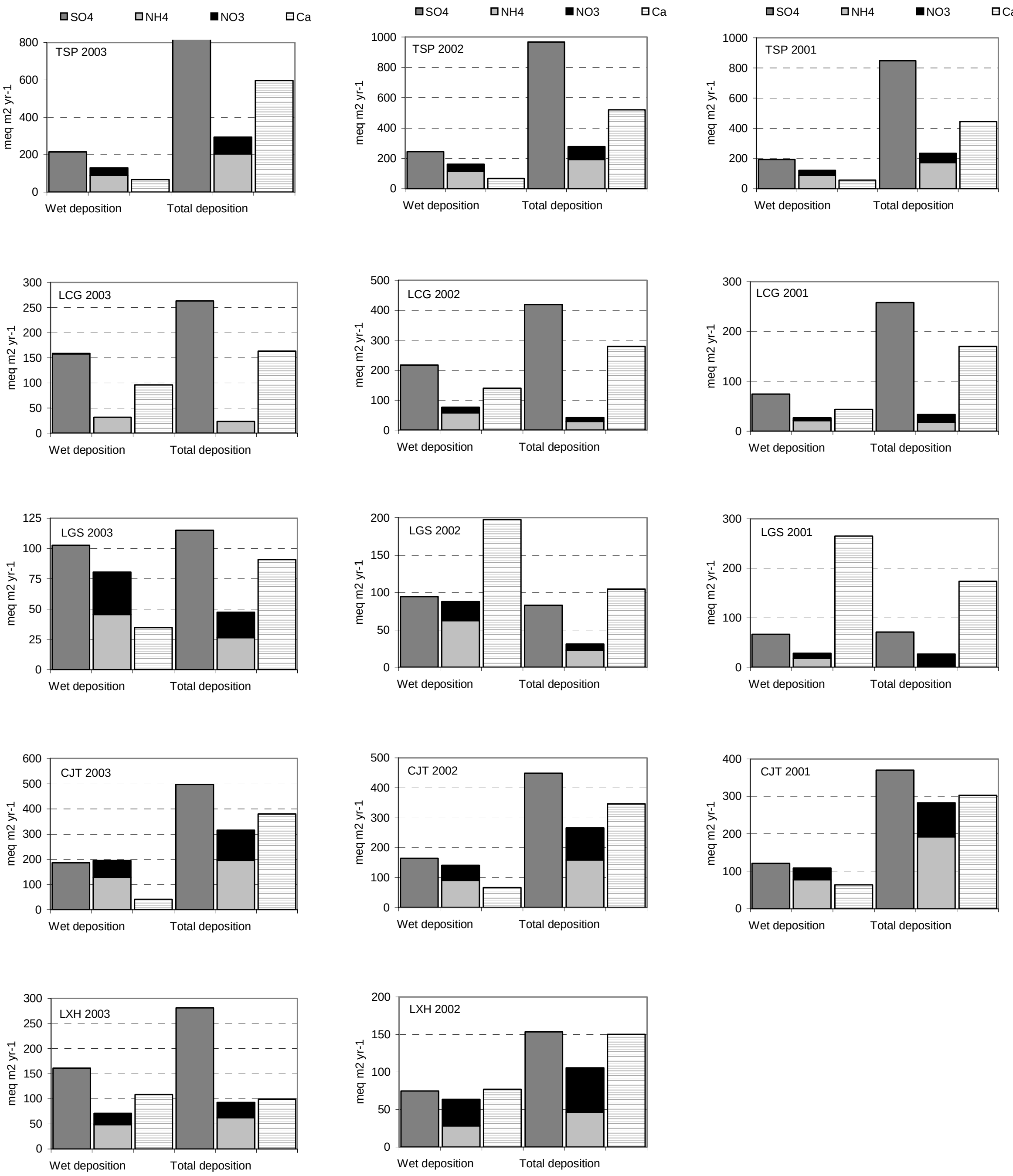

Figure 5. Wet- and total deposition of SO_4^{2-}, NH_4^+, NO_3^- and Ca^{2+} in 2002 and 2003, $meq^{2-}yr^{-1}$. For LGS the wet Ca deposition is probably overestimsated for 2001 and 2002. For nitrogen, wet deposition is used for total deposition at LCG and LGS since wet deposition of nitrogen was higher than throughfall deposition at these sites.

3.3 Soils, soil water and streamwater

Deposition of SO_4 and NO_3 is accompanied by Ca and NH_4, as shown in the previous paragraph. This indicates that most of the potential acidity associated with SO_4 and NO_3 is already neutralised by atmospheric Ca particles and NH_3 before precipitation infiltrates into the soil. Consequently, the total input of free H^+ is moderate (TSP) to very low (all other sites). It should be stressed that this does not imply that there is no acidification of soils or water in the catchments. On the contrary, ammonium (NH_4^+) will produce acidity in the soil when taken up by vegetation or through nitrification. The acidifying effect depends on the degree of leaching of the anions SO_4 and NO_3 to the streamwater and to what extent the anions are followed by base cations (e.g. Ca, Mg) or acid cations (e.g. H^+, Al). An important conclusion that may be drawn at this point is that pH of rain water is a poor indicator for the acidification potential of atmospheric deposition in the catchment.

After deposition the chemical composition of water that is moving through the catchment is strongly modified by biogeochemical processes in the soils. The most prominent of these processes are immobilisation of sulphate (SO_4), calcium (Ca) and nitrogen (N). For the catchment as a whole, the net result of these processes is acid neutralization, creating nearly neutral stream water (pH 6.5 to 7) at three of the sites (LGS, CJT and LXH; Figure 6). Although the same processes are present at TSP and LCG, net neutralisation of the moving water is less pronounced here and stream water is acidic, reaching median pH values of 4.7 and 4.3 in 2003, respectively.

It is important to note that a considerable proportion of the net-sorption of SO_4, NO_3 and Ca occurs in the sub-soils, i.e. below the deepest lysimeters. Probably, the different sensitivity of surface waters for acidification (Figure 6) is related to the character of the geologic substrate. Sedimentary bedrock like sandstone, shale and limestone may neutralise acid water draining from the acidic surface soils.

When considering the upper 50 cm of the soils (the root zone), a pronounced local acidification is observed at some of the sites. Further acidification of the soils results in mobilisation of potentially phyto-toxic aluminium (Al) at all IMPACTS sites, except LGS. Concentrations of Al in soil water at TSP are high compared to values reported for Europe and North-America, with median values ranging from 140 to 908 μmol/L in 2003. Also LCG (median concentration up to 160 μmol/L in 2002) and CJT (median concentration up to 140 μmol/L in 2003) have high Al concentrations. At the remote LGS site, where soil pH is higher, the concentration of Al in soil solution is low.

Elevated concentrations of Al are believed to cause root damage and reduced uptake of important nutrient cations like magnesium (Mg) in trees. Because of its potential negative effect on tree growth and tree health the Al concentration in the upper soil layers is generally used in critical load calculations. It has been suggested that Ca and Mg, two dominant cations in soil water, mitigate the toxic effects of Al. Therefore the molar ratio of Al to the sum of Ca and Mg in soil water is commonly used as an indicator for potential damage to trees due to acidification. A molar Ali/(Ca+Mg) ratio of 1 is generally assumed to be a critical limit in critical load calculations in Europe. The relevance of this ratio in China is uncertain and further research on this is required. For most samples the Ali/(Ca+Mg) ratios are below 1 (Figure 7). The highest values are commonly observed at TSP and LXH, which are the sites with the lowest base saturation (Figure 8).

Compared to soil water, stream water has low concentrations of NO_3. Some NO_3 removal may be due to denitrification, a process that produces N_2O, a potent greenhouse gas. Current concentrations of NO_3 in soil water at TSP and CJT (90-percentile values up to 1500 μmol/L or 21 mg NO_3-N/L in 2003) are high, but still below internationally accepted maximum levels for NO_3 in drinking water (1800 μmol/L or 25 mg NO_3-N/L; Figure 9 to Figure 13).

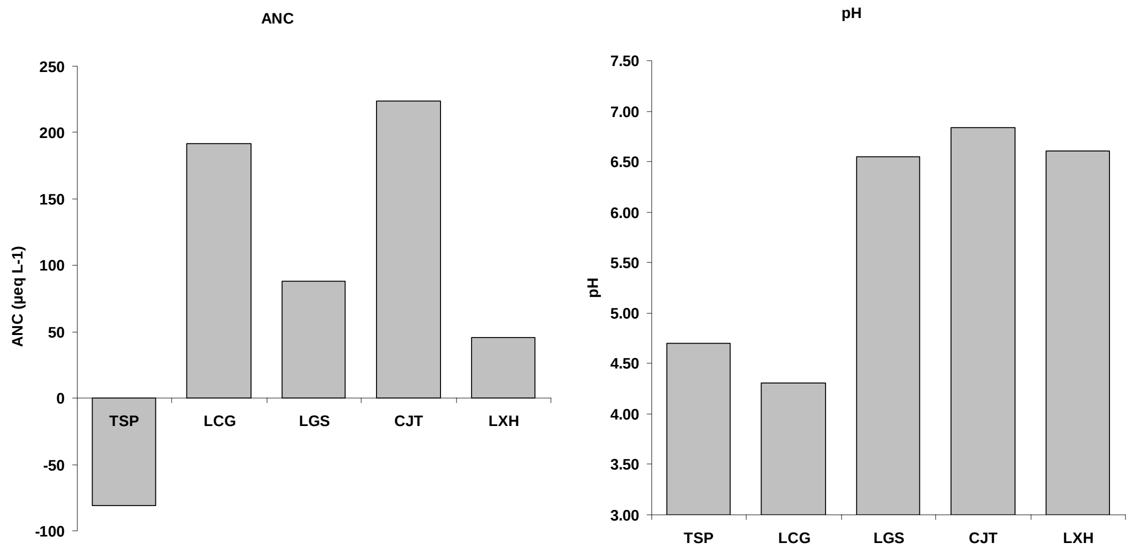

Figure 6. Acid neutralizing capacity (ANC) and pH in stream water from the five sites. Values shown are annual averages for 2003.

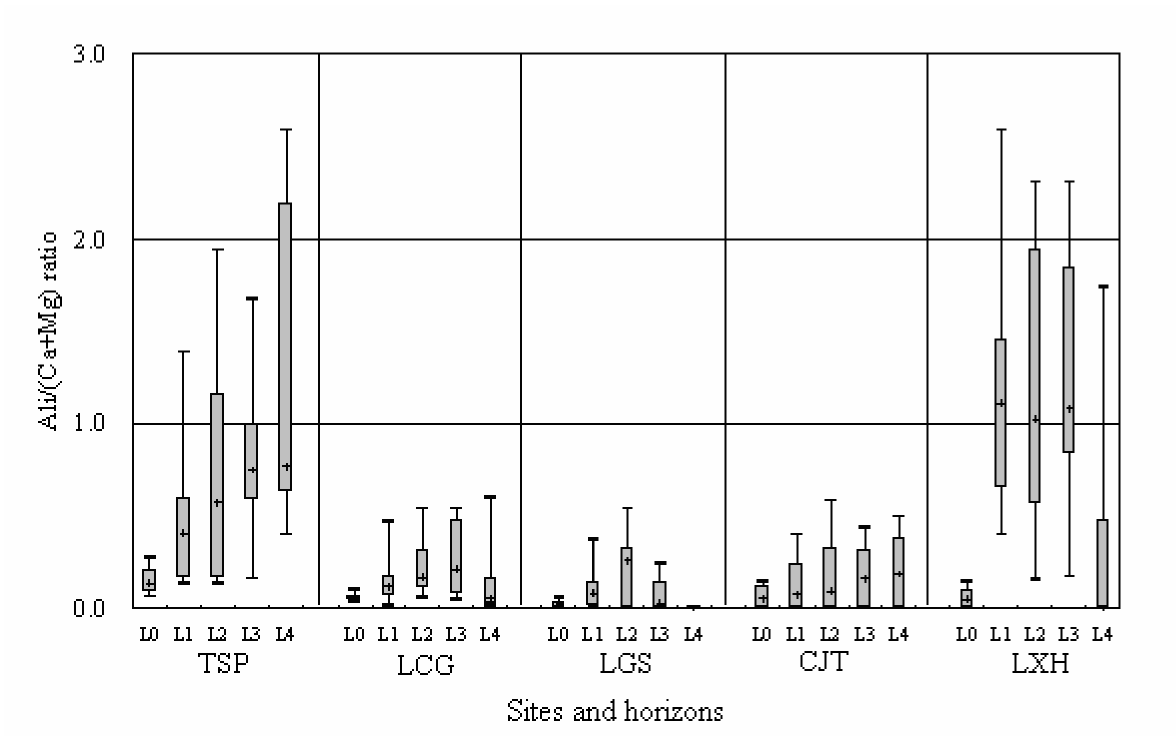

Figure 7. Median (+), quartiles (boxes) and 10/90 percentiles for the molar ratio of inorganic Al (Ali) to Ca and Mg (Ali/(Ca+Mg)) in soil solution from different soil horizons at each site. This ratio is often used in critical load calculations as indicator for potential negative effects on forest.

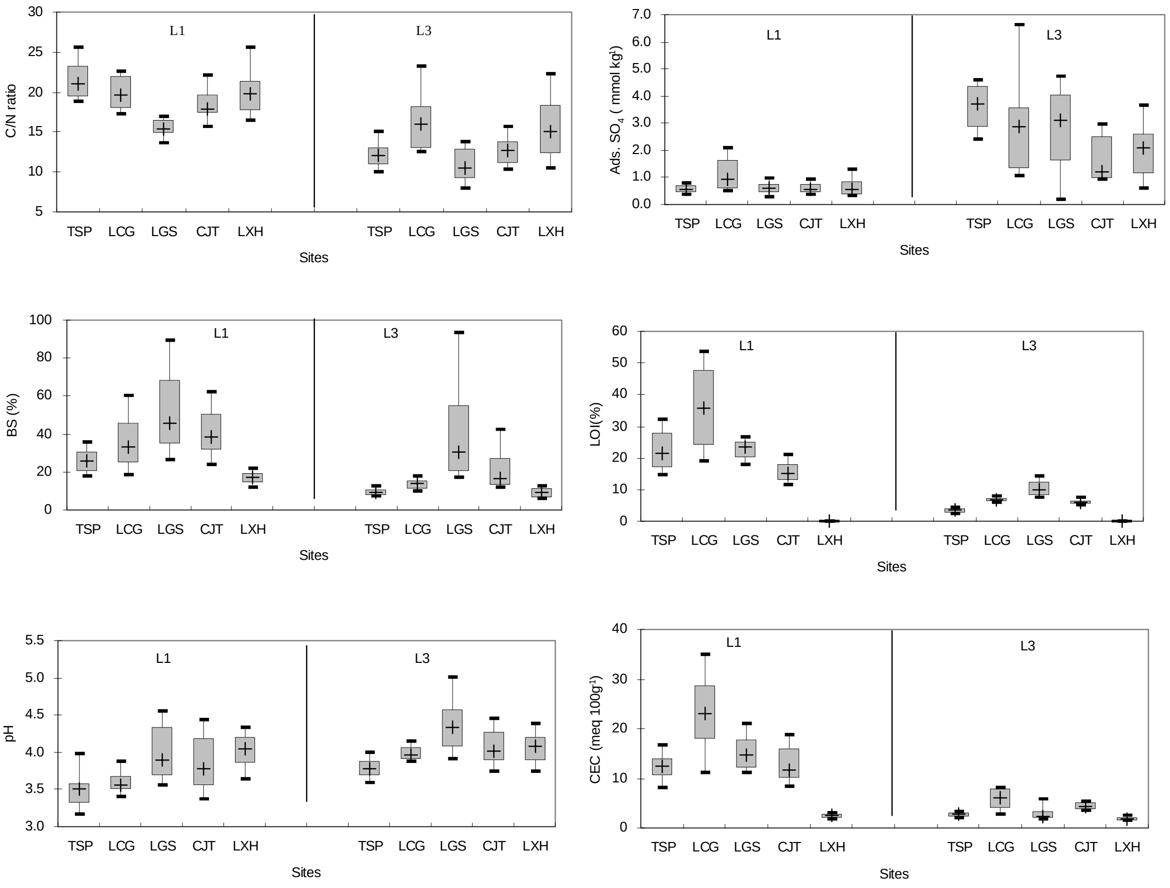

Figure 8. Statistical summary of some important soil properties. The boxes illustrate the quartiles, the upper and lower lines the 10 and 90%-iles and the middle cross the median values.

The major characteristics of soils, soil water and stream water are briefly discussed for each site. Soil data are reported in Appendix B.

3.3.1 Tie Shan Ping

Soils are silty loam to loam with a bulk density increasing from 1.25 kg dm^{-3} in the A-horizon to 1.34 kg dm^{-3} in the B-horizon. Water retention characteristics are similar for the A and B-horizon and typical for clay rich soils. Water contents in the A-horizon decrease from 36% at field capacity to 22% at wilting point. Residues of primary minerals include quarts and K-feldspar. Secondary minerals are dominated by kaolinite, but small amounts of smectite and illite are also present. The soil pH (pH_{H2O}) is the lowest among the studied sites (Figure 9). The base saturation (BS; Figure 8) is above 20% in the A-horizon and below 20% in the B-horizons (L3). The B horizon has the highest amounts of adsorbed SO_4 among the studied sites. At the pH values observed kaolinite may have a net positive charge, thus contributing to adsorption sites for SO_4 and to the net anion exchange capacity.

Throughfall water, soil water and stream water at TSP (Figure 9) have a low pH (<4.7). The dominant anions are SO_4 and NO_3. The major cations in the different compartments are NH_4, Ca and Al. Calcium is the dominant cation in throughfall and the upper soil horizons. In deposition NH_4 is an important cation, but due to nitrification and uptake its concentration decreases strongly in the A-horizon. Ammonium is neither found in mineral soil horizons (L1– 4), nor in stream water. In deeper soil layers Al becomes important.

A low Acid Neutralising Capacity (ANC) decreases from – 156 µeq L^{-1} in wet only precipitation (WO) to -788 µeq L^{-1} in the B horizon (L2), despite the high deposition of alkaline dust. The decrease in ANC (which is the same as an increase in acidity) is due to the elevated dry deposition of S- and N-compounds. In the L3 and L4 layers the ANC stays low (-1217 and -1347 µeq L^{-1}, respectively). In stream water the ANC is -73 µeq L^{-1}, implying partial neutralisation of the water in deeper soil horizons, due to a relatively important immobilisation of SO_4 and uptake of NO_3.

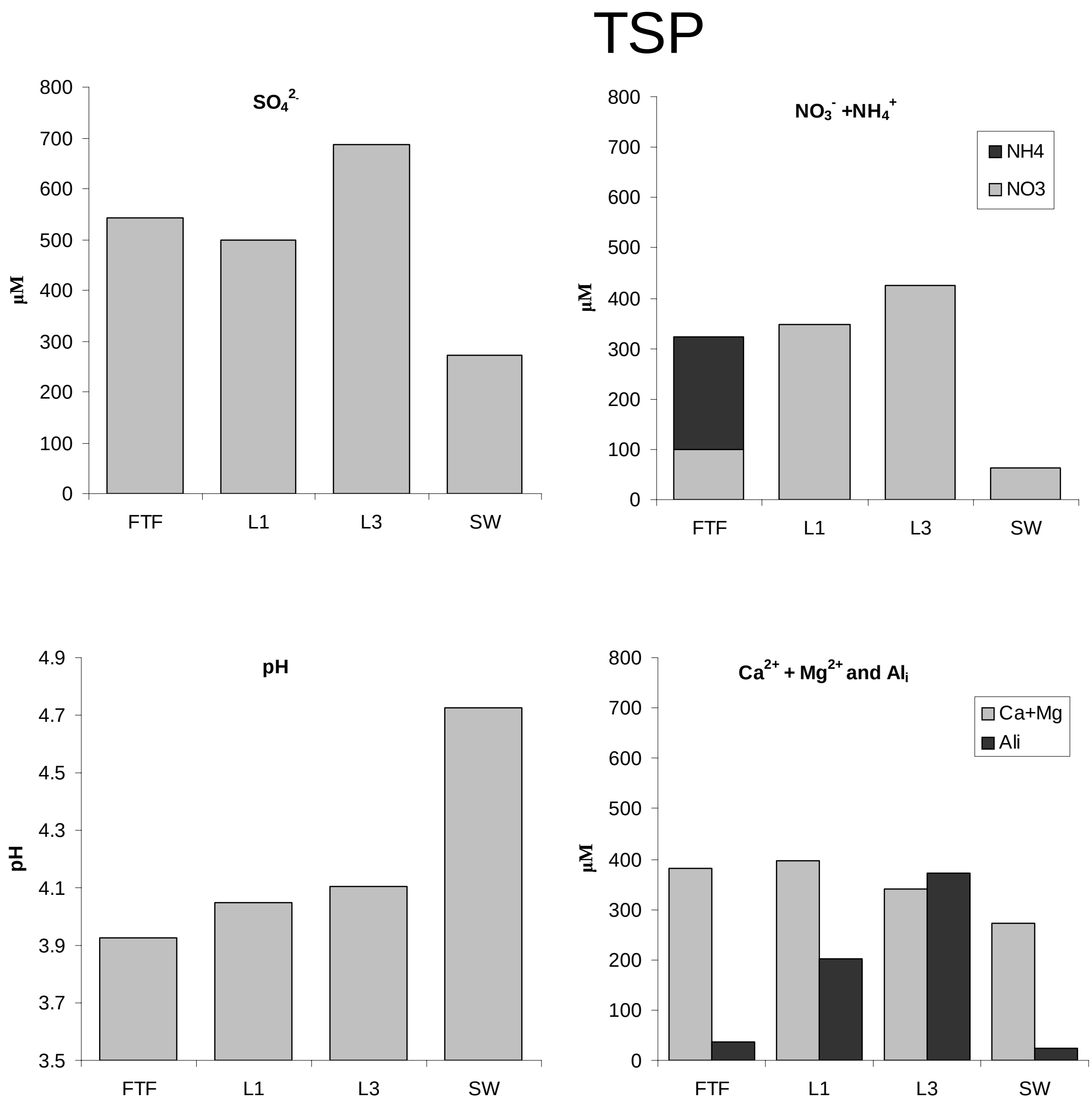

Figure 9. Concentrations of selected ions in throughfall, soil water and stream water at Tie Shan Ping in different compartments of the catchment. Values are volume-weighted averages (FTF) and medians (L1, L3 and SW), respectively of all samples for 2003.

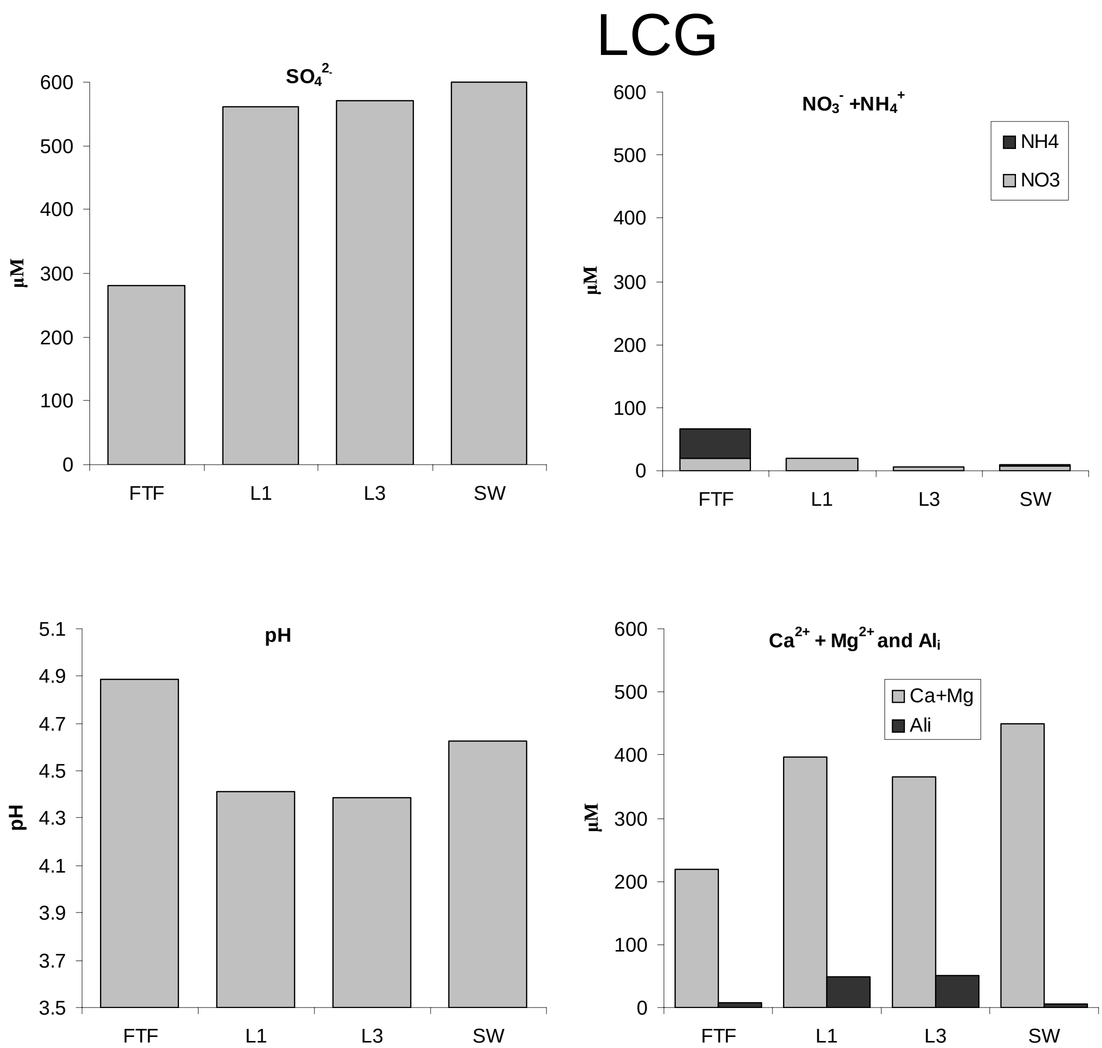

Figure 10. Concentrations of selected ions in throughfall, soil water and stream water at Liu Chong Guan in different compartments in the catchment. Values are volume weighted averages (FTF) and medians (L1, L3 and SW), respectively for 2003.

3.3.2 Liu Chong Guan

Soils are clay loams, but there is some variability at the site, with deeper organic rich profiles east of the dam. Probably, the enrichment with organic matter is a result of erosion higher up on the hillslopes. The catchment has buried soils in several places. The mineralogy in the catchment is rather homogenous, dominated by quartz and kaolinite. Soils are acidic (pH < 4), but with slightly higher pH values than those at TSP. Also the base saturation values are somewhat higher than those at TSP.

Throughfall water (pH 4.9) and soil water (pH 4.4) are slightly less acidic than the values observed at TSP (Figure 10). Similar to TSP, an extremely low pH in throughfall does not occur despite the high SO_4 concentrations, due to input of alkaline dust. The dominant anion is SO_4^{2-}, in all the compartments. By contrast to TSP, the concentration of N in deposition and of NO_3 in soil water is low. Calcium is the major cation in all compartments. In precipitation and throughfall Mg is also an important cation. In the soil, Al is released due to acid conditions, but its concentration decreases in stream water. As at TSP, this is due to processes in the deep soil layers (Larssen et al., 1998). The ANC in the ground vegetation throughfall is -112 µeq L^{-1} decreases to –315 µeq L^{-1} in the A-horizon (L1). In the stream water the ANC is -142 µeq L^{-1}, implying neutralisation of the water in deeper soil horizons.

3.3.3 Lei Gong Shan

The loamy soils are composed of residues of primary minerals as quarts and some K-feldspar and plagioclase. Secondary minerals are dominated by kaolinite, smectite and illite. There is also a significant amount of calcite in the soil (0.6 – 5.7 w/w %). The B-horizon (L3) at LGS contains more humus (9.8 w/w %) than this horizon at the other sites. The soil pH (pH_{H2O}) is the highest among the studied sites and the base saturation (BS) is above 20% in both the A- (L1) and B- (L3) horizons (Figure 11). This may be due to the presence of calcite in the soil. Despite the relatively low nitrogen deposition rate, the A and B horizons have the lowest C/N ratios of all IMPACTS soils.

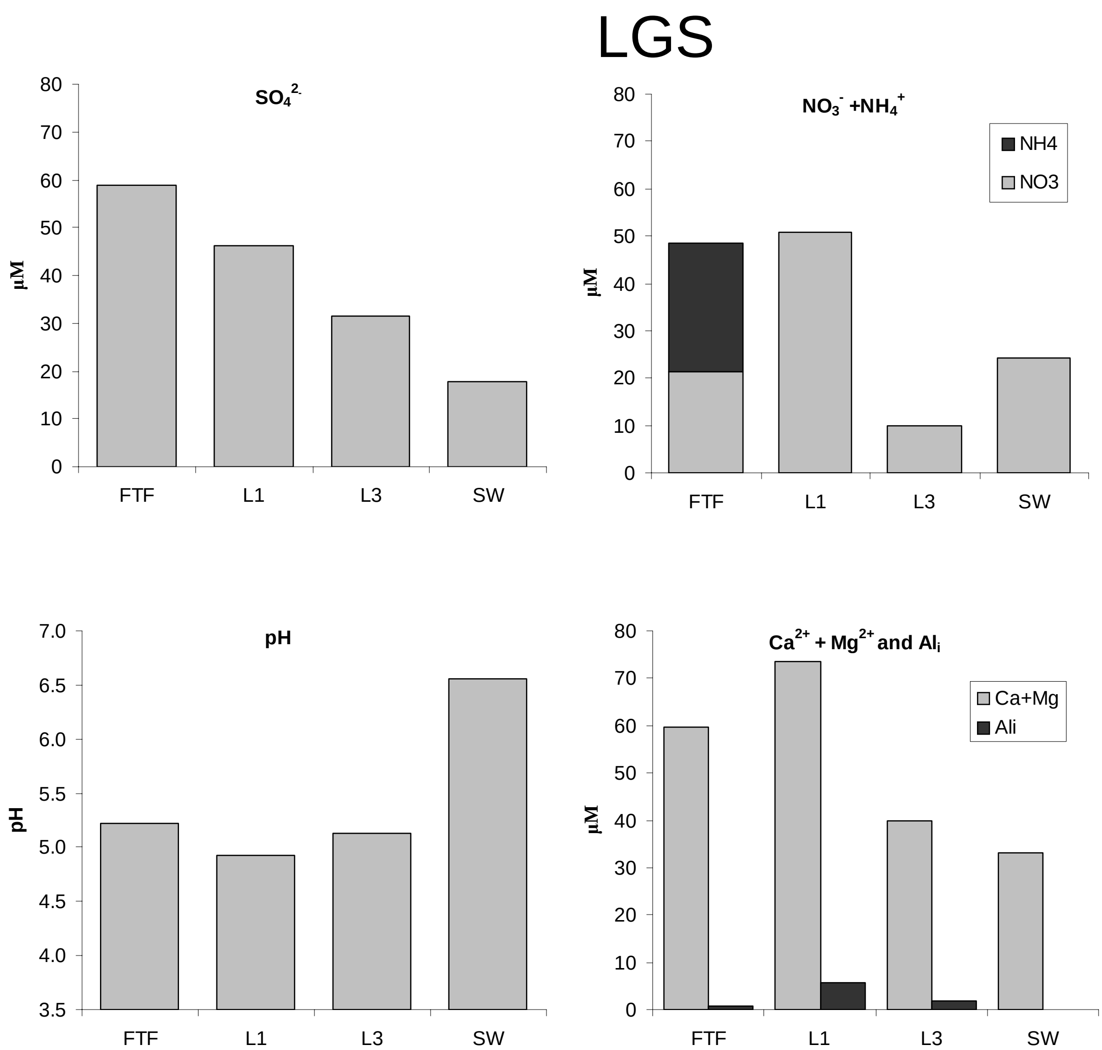

Figure 11. Concentrations of selected ions in throughfall, soil water and stream water at Lei Gong Shan in different compartments in the catchment. Values are volume weighted averages (FTF) and medians (L1, L3 and SW), respectively for 2003.

In all compartments of the LGS catchment the pH values of water are greater than 4.8. Highest values are observed in stream water, where pH = 6.6 (Figure 11). Besides SO_4, bicarbonate (HCO_3^-) is important in many of the precipitation samples. Organic anions are important in throughfall and upper soil horizons (Appendix B). Compared with TSP, the concentration of NO_3 at LGS is low in all compartments of the catchment. However, NO_3 levels are somewhat higher than those at LCG. The dominant anion in stream water is bicarbonate. Calcium is the major cation in all the compartments. Only small amounts of Al are mobilized in the LGS soils, so that the molar Ali/(Ca + Mg) is low (Figure 7).

Associated with the important role of HCO_3 and organic anions in water moving through the catchment, we observe relatively high ANC values, slightly decreasing from 38 µeq L^{-1} in ground vegetation throughfall (FTF) to about 0 µeq L^{-1} in the B horizon (L2). Below this horizon the ANC increases again into the BC horizon (L3; 5.9 µeq L^{-1}) and stream water (82 µeq L^{-1}) as the acidity is neutralised partly due to SO_4 adsorption. A relatively high concentration of sodium (Na) in the stream (80 µeq L^{-1}) suggests that the increased ANC may be partly due to the weathering of plagioclase in deeper soil horizons. Ionic strength of stream water is low at LGS (217 µeq L^{-1}) indicating that this dilute water has a low acid buffering capacity. Future anthropogenic acidification may therefore give rise to acid surface water.

3.3.4 Cai Jia Tang

The loamy soils at CJT are dominated by quartz, with illite being the major clay mineral. The low amounts of weatherable primary minerals as feldspar and plagioclase imply that the soils are highly weathered and low in base cations. At the same time, the high content of illite may suggest that the soils at CJT are developed from a parent material relatively rich in base cations. Dolomite in the clay fraction of the A-horizon of the soil profile located in the valley bottom also suggests the presence of a considerable pool of base cations in the catchment.

Soil pH and base saturation, although variable, are relatively high (Figure 8). Particularly the soils in the lower part of the catchment have relatively high BS. Despite the elevated S deposition levels, the amount of adsorbed SO_4 is relatively low. This may be due to the relatively high soil pH.

By contrast to TSP, the CJT site has relatively high concentrations of Ca and NH_4 in throughfall deposition compared with SO_4. This results in a higher pH, and thus lower deposition rate of free H^+ at CJT, than at TSP. Upon transport of the water into the mineral soil the pH increases, despite a considerable nitrification. As for the soil, also soil water pH values vary considerably from soil profile to soil profile. The highest average soil water pH (6.0) is found in the deepest lysimeter in the valley bottom (plot C), while the average pH in the stream water is near-neutral (6.9).

Sulphate is the dominant anion in all the compartments, except for stream water. Nitrate also contributes considerably to the total negative charge in the transported water, with the exception of the stream water. Bicarbonate accounts for about half of the anionic charge in the stream water. Calcium is the major cation in all compartments. Due to uptake of K and Mg (not shown) in the B2 horizon (L3), the pH decreases to 5.0 and the Al concentration increases. In all cases the molar Al/(Ca + Mg) ratio remains well below 1 (Figure 7).

The ANC decreases from -134 µeq L^{-1} in the ground vegetation throughfall (FTF) to -172 µeq L^{-1} in the B horizon (L3) due to uptake of base cations and release of Al. In stream water the ANC is 223 µeq L^{-1} (Figure 6), indicating total acid neutralisation of the water in the deeper layers of the soil and the bedrock.

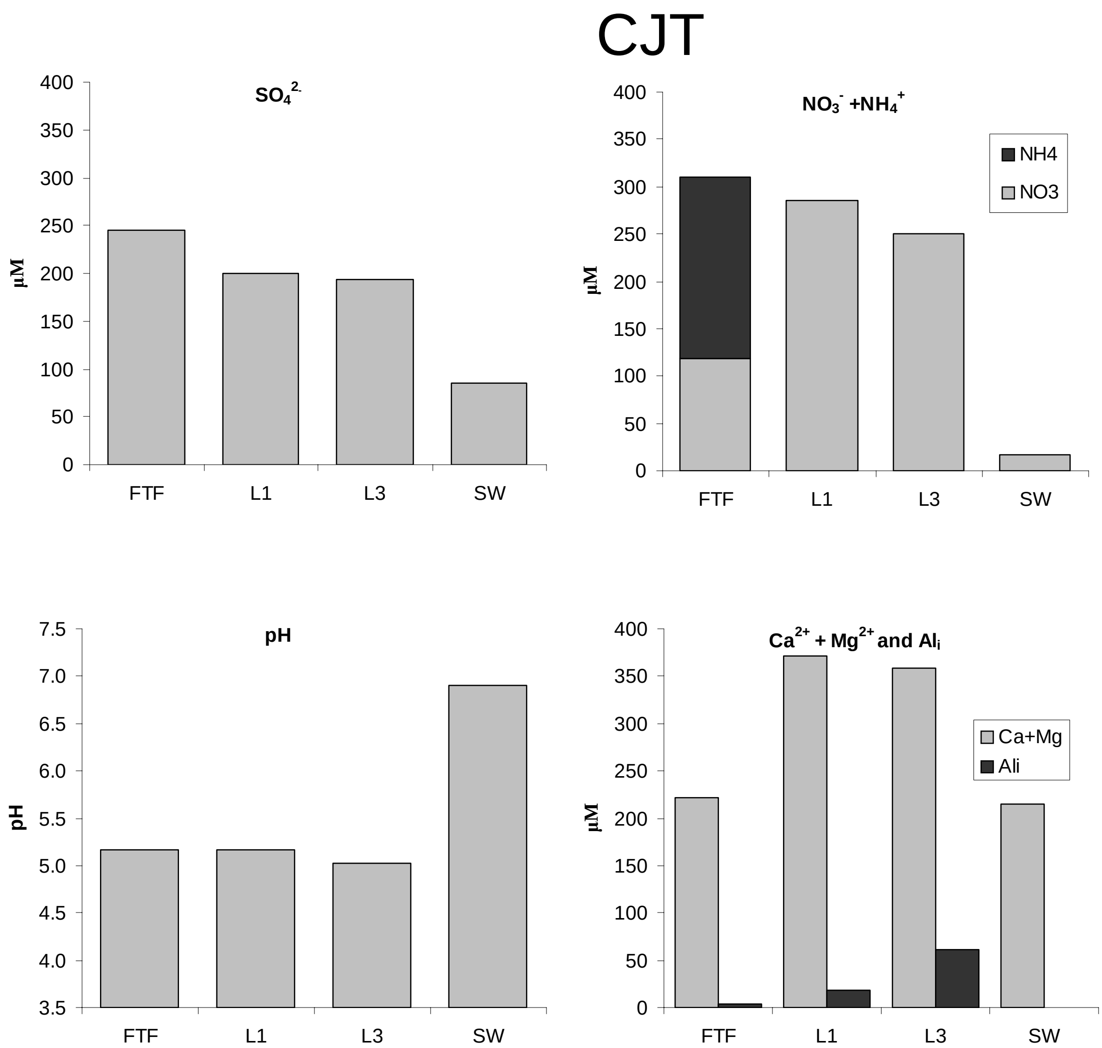

Figure 12. Concentrations of ions in throughfall, soil water and stream water in Cai Jia Tang in different compartments in the catchment. Values are volume weighted averages (FTF) and medians (L1, L3 and SW), respectively for 2003.

3.3.5 Liu Xi He

The soils at the LXH site are rather sandy. The soils contain a considerable amount of K-feldspar and quarts. Among the secondary minerals the amount of illite was higher than found at the other sites. Furthermore, the soils contain a substantial amount of gibbsite. The bedrock at LXH is igneous instead of sedimentary, as is the case at the other sites. The content of organic matter in the soils at LXH is relatively high.

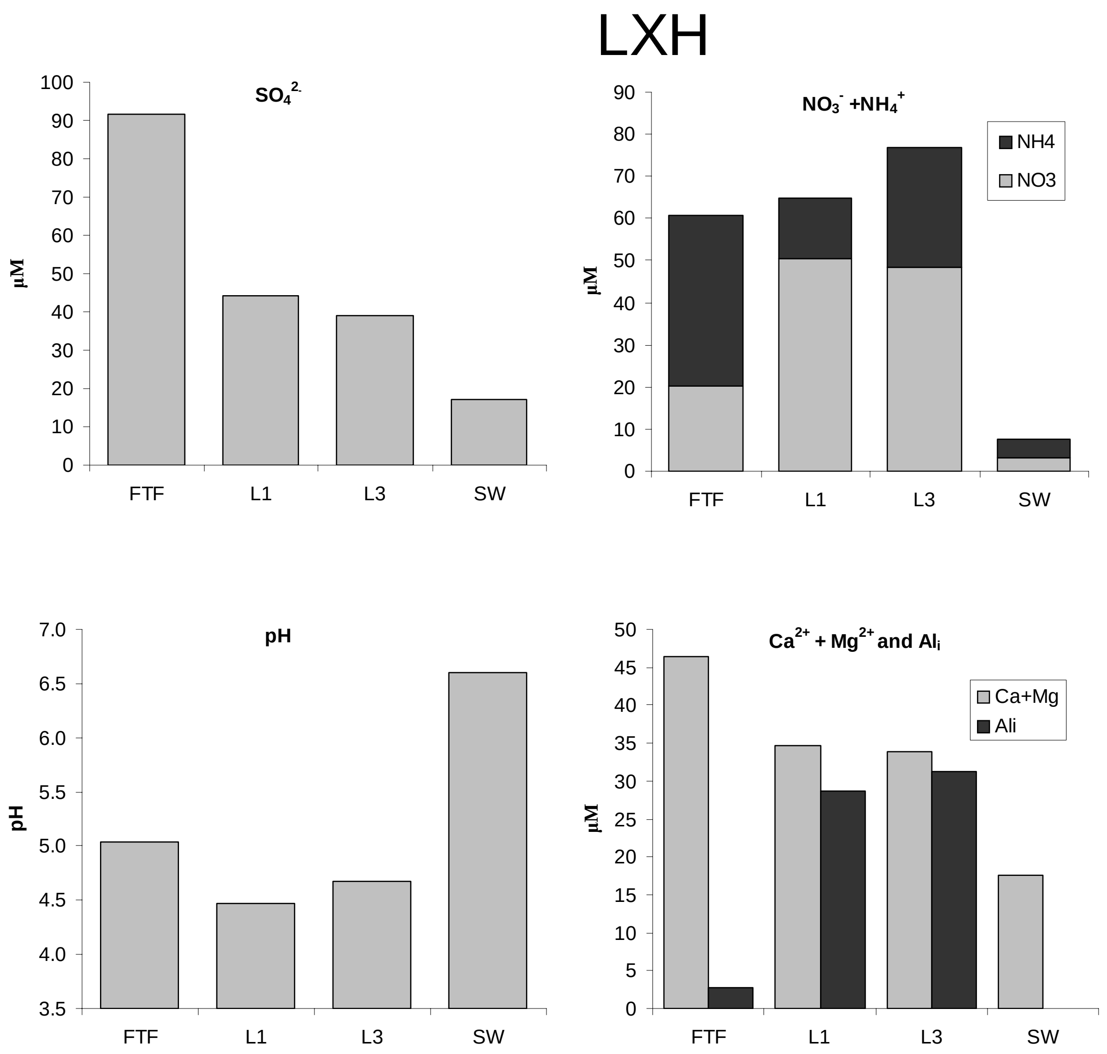

Figure 13. Concentrations of selected ions in throughfall, soil water and stream water at Liu Xi He in different compartments in the catchment. Values are volume weighted averages (FTF) and medians (L1, L3 and SW), respectively for 2003.

Water pH varies between 4.4 and 5.2 in all compartments of the watershed, except for the stream water, which has median pH of 6.6 (Figure 13). Because the atmospheric deposition rates of SO_4, Cl and N at LXH are similar, these ions also constitute the dominant anions in the different compartments. Bicarbonate plays an important role in stream water (Appendix B). Nitrate accounts for about half of the anionic charge in the mineral soil horizons due to the nitrification. The major cations in the different compartments are Ca, K, Al, and Na. In the A- and B horizons Al is dominant and in many cases the molar Al/(Ca + Mg) is greater than 1. This suggests that the critical load at this site has been exceeded.

The ANC in stream water is 39 µeq L^{-1} (Figure 6), indicating that also at LXH acid neutralisation occurs in deeper soil horizons.

3.4 Modelling of future scenarios

Modelling of the response to future scenarios for changes in deposition is carried out in IMPACTS using two different models: MAGIC and NuCM. Both are process-based dynamic models, but are of different complexity in terms of processes and details included. MAGIC is less detailed and hence requires less input data. NuCM has detailed process description and require detailed information as input. A major difference between the two models is the description of nutrient cycling, where MAGIC take nutrient cycling fluxes as inputs, NuCM include the nutrient cycling processes. Monitoring data are necessary to calibrate such models and data from the IMPACTS sites form a very good basis for model calibration. The MAGIC model has been applied to the data from TSP, CJT, and LGS sites. NuCM has so far only been applied to the TSP site.

3.4.1 MAGIC

Some model results for different scenarios for the LGS site are presented here. As indicators for acidification of soil and soil water the molar ratio of base cations[2] to aluminium (Bc/Al) and the soil base saturation (BS) are used. Detailed results on model calibration results and scenario analysis will be published in a separate report.

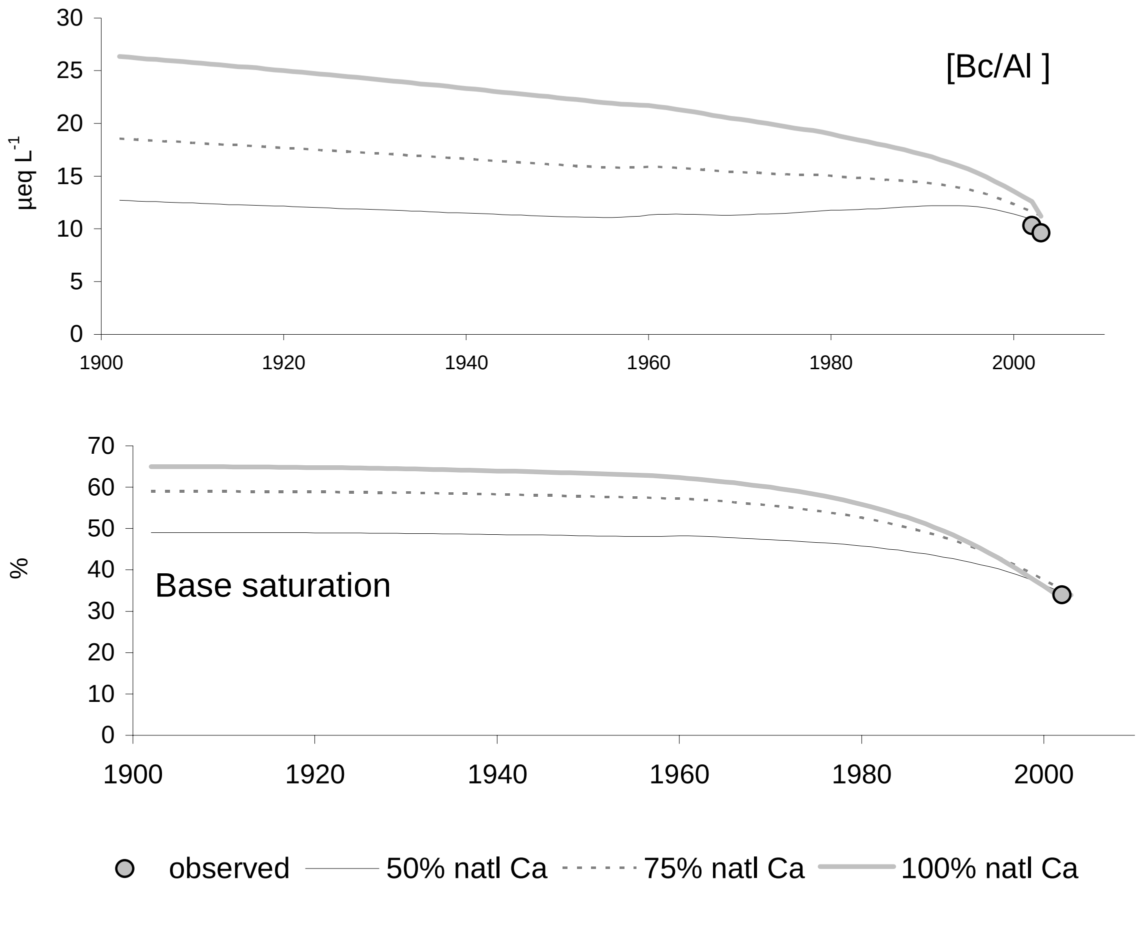

Figure 14. Historic development of the acidification indicators Bc/Al molar ratio in soil solution and soil base saturation for the average of the LGS catchment using 3 different assumptions for sources of the base cation deposition. The results show that better knowledge of the sources of the alkaline dust in the atmosphere is important for model calibration.

[2] Here only the base cations Ca, Mg and K are included (since Na is assumed to have only minor influence on the biota); the abbreviation Bc is used for these three base cations.

It has earlier been pointed out that the deposition of base cations, in particular calcium, is of major importance for understanding the effects of changes in emissions of acidifying compounds in China. In order to illustrate this we show the result of three different model calibrations for the LGS catchment. The average values for the different plots in the catchment were used. Three different assumptions for the origin of the base cations were used, assuming from 50% to 100% of the current base cation deposition having natural origin. Assuming a large natural fraction of the current base cation deposition (and hence constant over time) gives a larger predicted change in the acidification parameters. If a large fraction is assumed anthropogenic (and the historic deposition pattern scaled to sulphur), the estimated historic acidification is smaller (Figure 14).

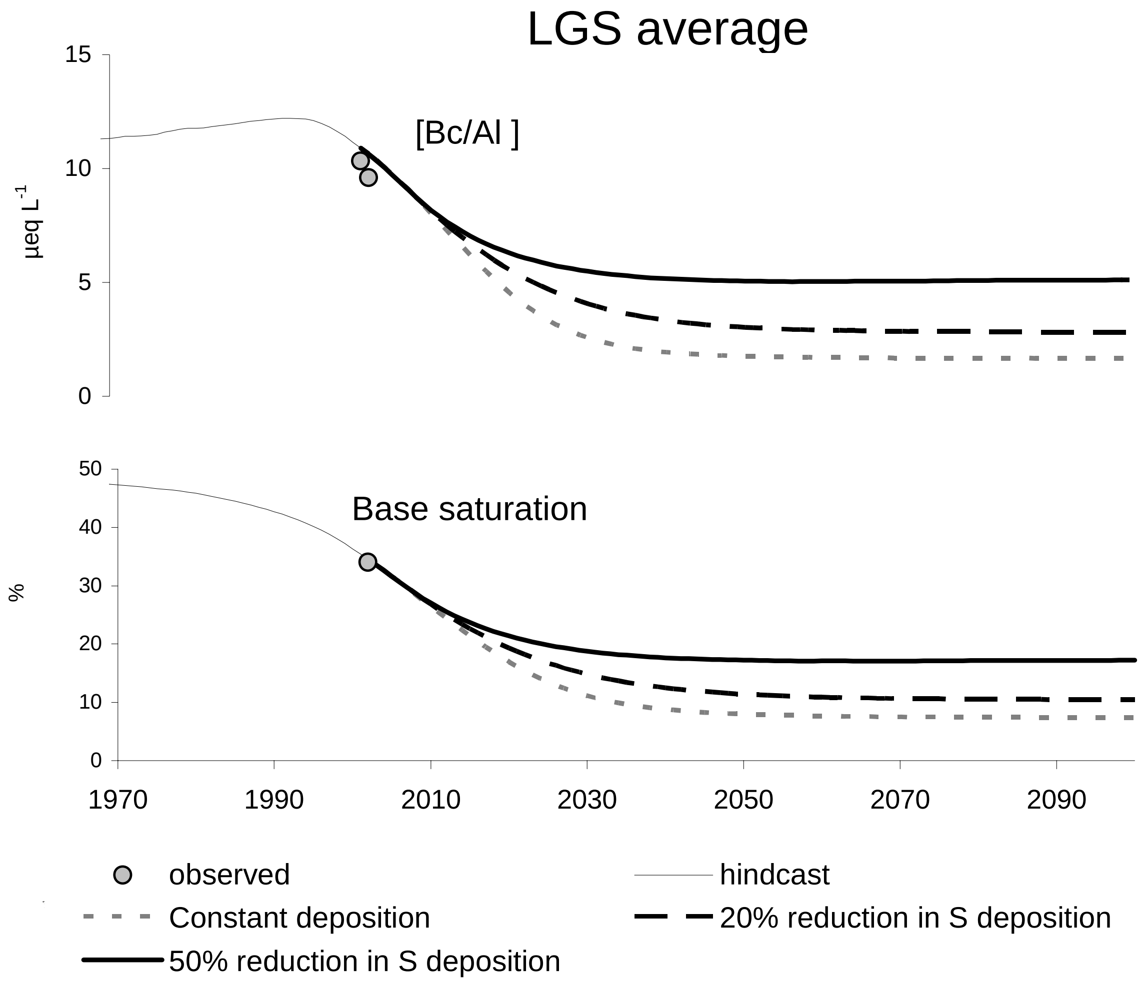

Figure 15. Predicted future development for the acidification indicators Bc/Al molar ratio in soil solution and soil base saturation for the average of the LGS catchment using 3 different scenarios for sulphur deposition.

For the forecasts presented here we used the model calibration assuming 50% of the base cation deposition of natural origin for the LGS site. For the CJT site we used an assumption of 25% natural base cation deposition. A lower percentage natural contribution is used for the CJT site due to its location closer to agricultural and other anthropogenic activities. Three different forecast deposition scenarios are presented:

- All deposition constant at current level
- Sulphur deposition reduced by 20% by 2010 (i.e. according to the current legislation)
- Sulphur deposition reduced by 50% by 2010

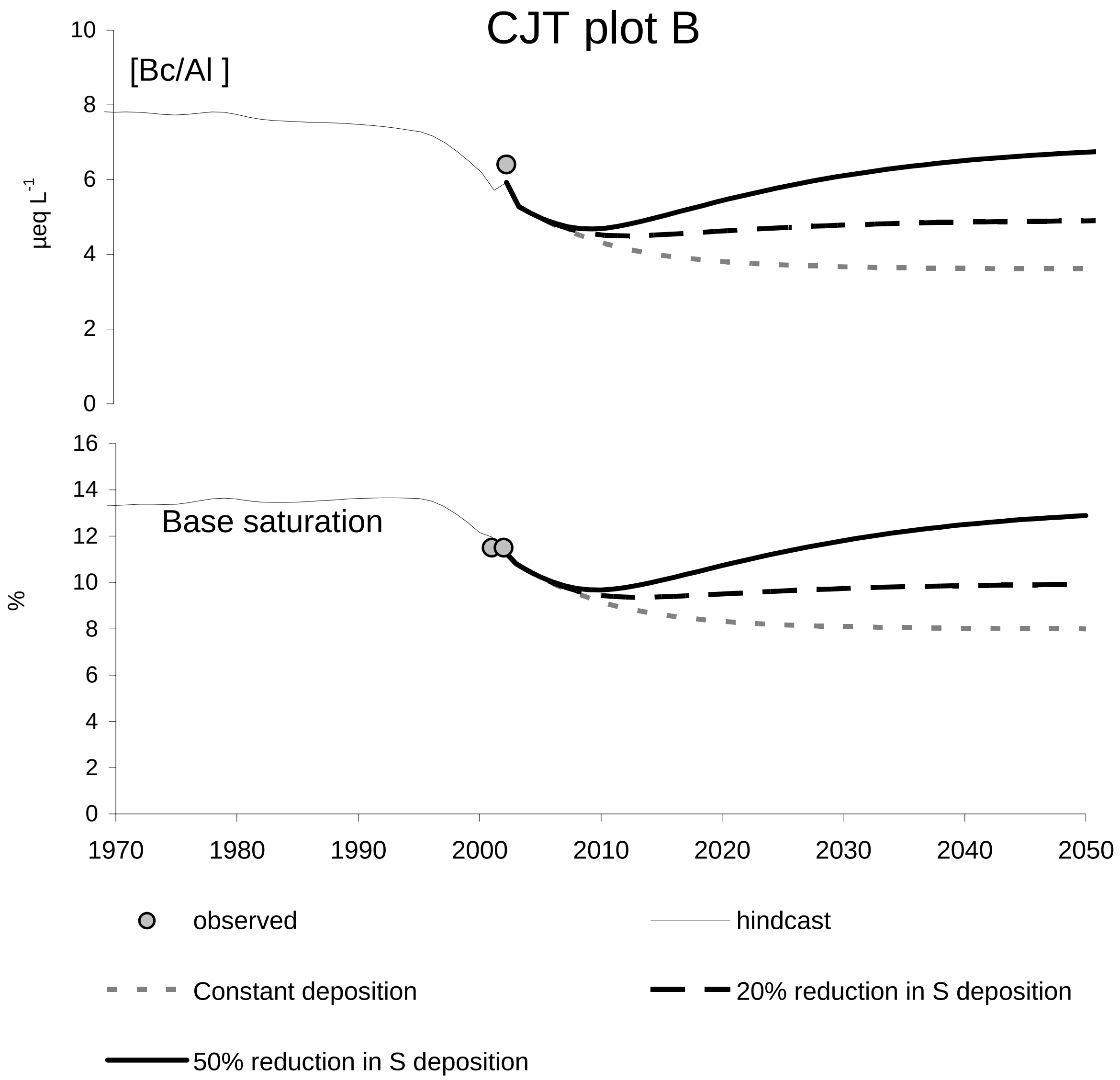

Figure 16. Predicted future development for the acidification indicators Bc/Al molar ratio in soil solution and soil base saturation for plot B at CJT catchment using 3 different scenarios for sulphur deposition.

For the LGS catchment all three scenarios give a continued decrease in the acidification parameters (Figure 15). The site is hence highly sensitive to acidification and the pool of exchangeable base cation is being reduced at the current deposition. A substantial reduction in the acid deposition is needed in order to stop further acidification of the soil. The high sensitivity to acidification is particularly related to the low pools of exchangeable cations in the soils at this site.

For the CJT site results are shown for Plot B (Figure 16). This site has according to the model experienced a moderate acidification previously. The model results suggest that at the current deposition the soils will continue to acidify. 20% reduction in the sulphur deposition is predicted to be sufficient to stabilize the soil and soil solution at values close to those found at present. The scenario with 50% decrease will according to the model give substantial improvements.
In the future, with the control of sulphur emission, sulphur deposition may decrease. However, nitrogen emission is expected to increase rapidly. Forecasts from current calibrations show that increased N deposition may play an important role in the future.

It should be noted that some of the observations at the sites are difficult to explain, and not in accordance with results expected from literature. In some cases it is not possible to explain the chemical mechanisms behind the observed data. This naturally makes model results very uncertain, since the processes are not well understood. It is hence important to carry out sensitivity analyses in model applications, as exemplified for the historic base cation deposition in Figure 14.

3.4.2 NuCM

The Nutrient Cycling Model (NuCM) was used to simulate the dynamics of nutrient cycling in an acid rain affected Masson pine (*Pinus massoniana*) forest ecosystem at Tieshanping, Chongqing city. In addition, future nutrient cycling in the investigated forest ecosystems was predicted in response to several acid deposition scenarios. Two years of observed data (from 2001 to 2002) were used for model calibration. All major biogeochemical processes affecting nutrient cycling in forest ecosystem are included in the NuCM simulation model.

After model calibration, water fluxes in the ecosystem were well simulated, even though the annual precipitation varied very much during the two simulation years. Dry deposition was obtained by calibration, using observed chemical fluxes in wet deposition and throughfall. Since data on foliar leaching and nutrient translocation are lacking, the required model parameters had to be obtained through calibration. Satisfactory results on throughfall calibration were achieved, while Ca and S fluxes in litterfall were underestimated. Rates of litter decay and organic matter mineralization were also obtained through model calibration.

Tree biomass increment was obtained from the literature, whereas the chemical composition of foliage was based on measured values. The chemical composition of boles and roots were taken from the literature.

In general, concentrations of cations, N and S in soil water were well simulated (Figure 1). Since there were no measured data on mineral weathering, selectivity coefficients and aluminum hydrolysis constants, all relevant parameters were found by calibration against observed cation concentrations in soil water (Figure 17).

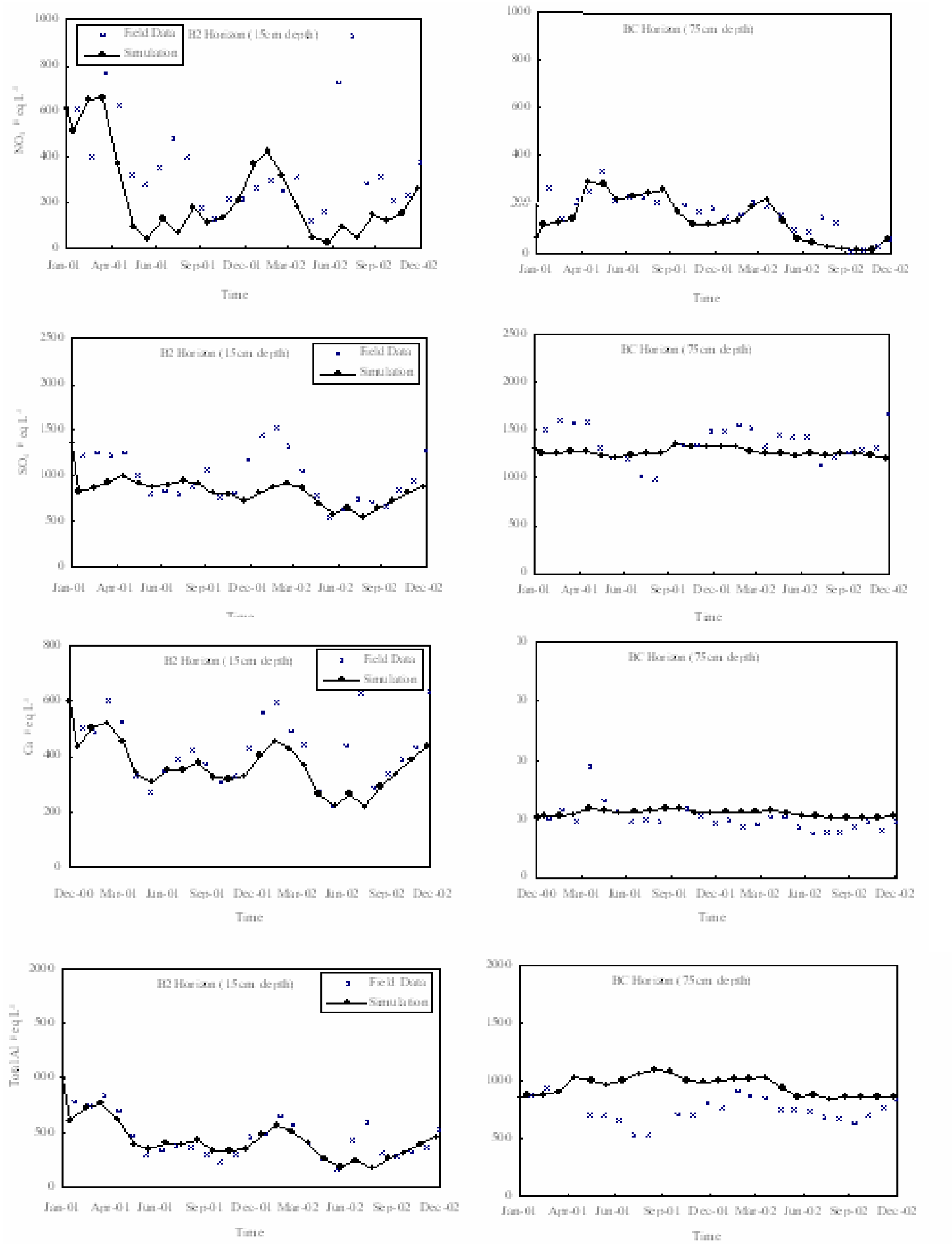

Figure 17. Simulated versus observed concentrations of NO_3, SO_4, Ca and Al in soil water at Tie Shan Ping plot C.

Sensitivity analysis suggests that vegetation growth rate, mineral weathering rate and organic matter decay rate were most important for model simulations of nutrient cycling. Additional research is necessary in order to obtain better estimates of parameter values that describe these processes. In addition, the sensitivity analysis indicates that model results are little affected by carbonate equilibria, atmospheric CO_2 levels, and soil temperature. Consequently, there is little need not to put much emphasis on further quantification of these variables.

After model calibration, NuCM was used to simulate selected scenarios. Four scenarios on different atmospheric S and N deposition loads were used: 1) keep current deposition rate constant for 50 years; 2) reduce S deposition by 50% from the first simulation year but keep others constant for 50 years; 3) reduce S deposition by 50% but increase NH_4 deposition by 100% from the first simulation year, and keep other deposition constant for 50 years; and 4) reduce S deposition by 50% but double NO_x deposition from the first simulation year, and keep other deposition constant for 50 years.

The results of scenarios simulations suggest that increasing N deposition increased vegetation growth in all the plots. Most of the added N accumulated in the ecosystem (vegetation and soil) and the model suggest that little additional N leaching occurs in the next 50 years even in the scenarios with increased N deposition. Additional experimental research is required to further test this. Reducing S deposition decreased leaching of nutrient cations like Ca and Mg and increased soil exchangeable Ca, Mg and K pools.

It is important to note that the current NuCM calibration has several uncertain parameters. For example, parameters for foliar leaching, nutrient translocation and mineral weathering are lacking. The great number of unknown parameters makes the calibration procedure difficult and make further model testing necessary.

3.5 Forest

Forest condition is monitored by visual crown assessments, foliar chemistry and observations of damaging agents. Defoliation has been severe during the four years of monitoring in the TSP catchment, and moderate or low in the others. In the LCG catchment defoliation has increased considerably throughout the monitoring period. Insect attacks have been severe on Masson pine (*Pinus massoniana*), again mainly in TSP. The insects have been both free-feeding defoliators responsible for defoliation, and Longhorn beetle larvae, living under the bark, apparently killing the trees. In CJT, another insect, the Masson-pine caterpillar (*Dendrolimus punctatus)* was frequent in 2002, but the adverse influence caused by it was less severe in 2003.

3.5.1 Defoliation

In general, defoliation has been severe and wide-spread in TSP, with mean values around 45%. Although lower, defoliation has also been considerable in LCG. The three other catchments had minor defoliation only. The defoliation index used in Europe and North America (ICP-Forests) are used here for classification:

- no defoliation: 0-10%
- slight defoliation: 10-25%
- moderate defoliation: 25-60%
- severe defoliation: >60%

In TSP, defoliation of dominant Masson pine increased during the 2000-2002, with averages from 41% in 2000 to 50% in 2002, followed by a slight decrease to 2003 (Figure 18, Table 6). The percentage of Masson pine in TSP in 2003 with slight defoliation has slightly increased, the percentage with moderate defoliation clearly increased while the percentage within the severe defoliation class decreased. Few trees died in 2003 compared to the previous years.

In LCG, the defoliation has increased during the four monitoring years of 2000-2003, with average defoliation from 15% in 2000 to 41% in 2003 (Figure 18, Table 6). The increase from 2002 to 2003 was 15%, which is more than the total increase of 11% during the three previous years. The percentage of Masson pine in 2003 with no defoliation and slight defoliation has strongly decreased, while the moderate and severe defoliation classes strongly increased; no dominant Masson pines died in 2003.

In LGS, 96% of the Armand Pine was in the no defoliation class in 2003. This is a slight change from 2001 nd 2002, with an increasing number of trees in the no defoliation class. For Chinese Fir 97% of the trees were in the no defoliation class. This is a considerable change from 2002 and 2001, where a considerable fraction of the trees were in the slight defoliation class (Table 7).

At CJT, 85% of the Masson pine was in the no defoliation class in 2003. This is a slight increase from the previous years. For Chinese Fir, a reduction of healthy trees and an increase of trees within the slight defoliation class were observed from 2001 to 2002 (Table 7). In 2003, only healthy trees were observed, showing the same tendency as both Armand pine in LGS and Masson pine in CJT did.

Forest investigations started in 2002 in LXH. At this site broadleaved trees dominate. The investigations document low defoliation.

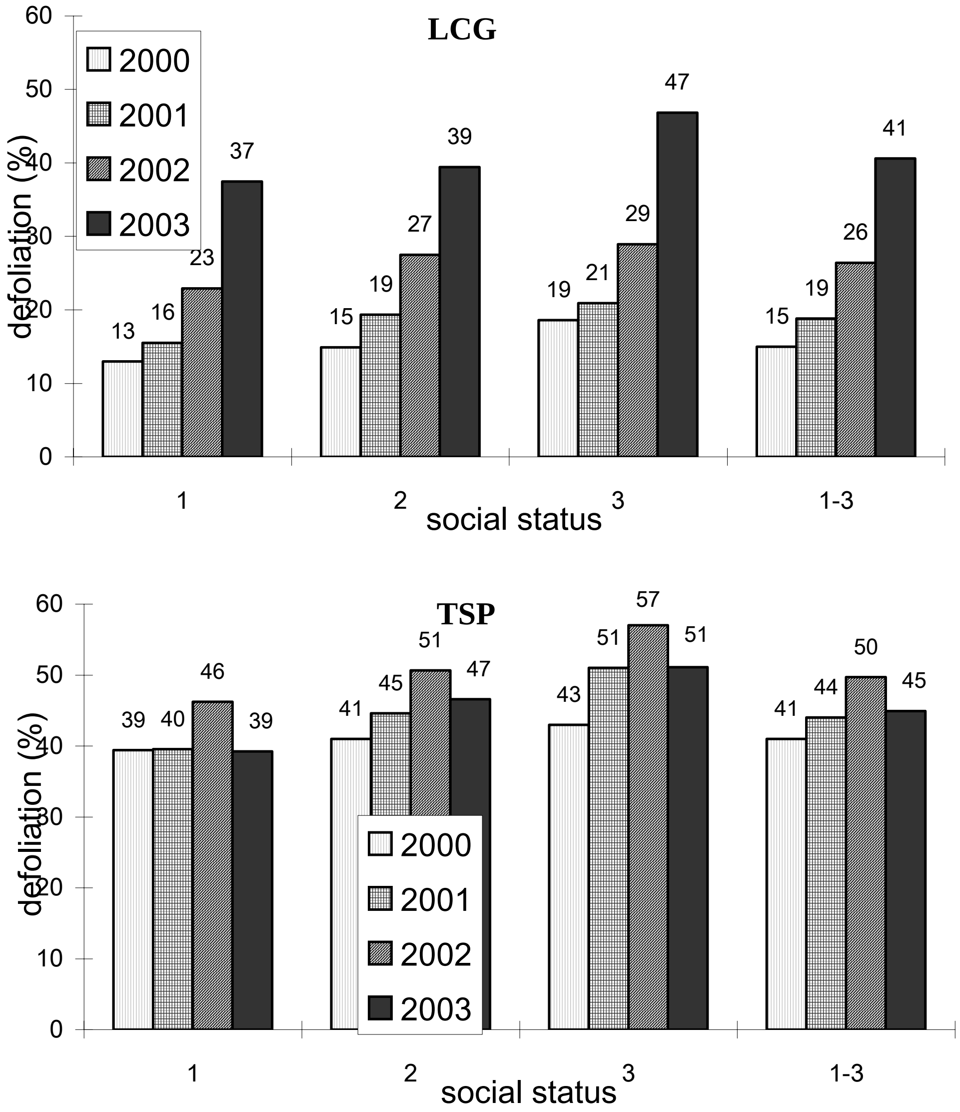

Figure 18. Variation in averaged defoliation of dominant Masson pines within Kraft class 1-3 in LCG and TSP from 2000 to 2003.

Table 6. Percentage distribution of Masson pine within different defoliation classes at the monitoring sites in 2000-2003

Catchment	Year	0-10%	10-25%	25-60%	> 60%	Dead (%)*
TSP	2000	8	17	63	12	0
TSP	2001	1	10	77	7	5
TSP	2002	0	5	69	18	8
TSP	**2003**	**0**	**7**	**79**	**12**	**2**
LCG	2000	51	34	13	2	0
LCG	2001	35	42	19	2	2
LCG	2002	12	49	34	3	2
LCG	**2003**	**2**	**26**	**59**	**13**	**0**
CJT	2001	80	3	1	4	12
CJT	2002	82	1	0	0	17
CJT	**2003**	**85**	**1**	**0**	**0**	**14**

*Percentage of dead trees in 2002 includes the dead trees in 2001.

Table 7. Distribution of dominant Armand pine, Chinese fir and broadleaves within different defoliation classes at the monitoring sites in 2001-2002

Catchment	Species	Year	0-10%	10-25%	25-60%	> 60%	Dead (%)
LGS	Armand pine	2001	89	6	5	0	0
LGS	Armand pine	2002	97	0	1	1	1
LGS	**Armand pine**	**2003**	**96**	**2**	**0**	**0**	**0**
LGS	Chinese fir	2001	63	28	9	0	0
LGS	Chinese fir	2002	51	41	8	0	0
LGS	**Chinese fir**	**2003**	**97**	**3**	**0**	**0**	**0**
CJT	Chinese fir	2001	82	12	6	0	0
CJT	Chinese fir	2002	57	38	5	0	0
CJT	**Chinese fir**	**2003**	**100**	**0**	**0**	**0**	**0**
LXH	Broadleaves	2002	86	12	1	1	0
LXH	**broadleaves**	**2003**	**85**	**9**	**5**	**0.5**	**0.5**

Defoliation assessment is hampered by the subjectivity of the observer. Therefore, defoliation scores are preferably substantiated with supplementary data. In some cases defoliation results from unusually high needle or leaf losses, which on conifers may be documented by counting needle retention. The needle retention seen in TSP follows the temporal variation in defoliation well. In LCG, at the contrary, there is no temporal correspondence between needle retention and defoliation. It is thus possible that the recent increase in defoliation is more linked to changes in branching structure (dying of twigs and branches, or sparse development of new twigs/branches) or needle size, than to needle loss.

Table 8. Needle retention of dominant trees (Kraft class 1-3) in each site

Sites	Tree species	2001	2002	2003
TSP	Masson pine	1.9 year	1.5 year	1.8 year
LCG	Masson pine	1.9 year	1.8 year	1.9 year
CJT	Masson pine	1.3 year	1.3 year	1.3 year
LGS	Armandi pine	1.9 year	1.6 year	1.3 year

Defoliation assessments are subjective, and minor differences should always be interpreted with care. Concerning the causes of variations in defoliation, the monitoring does not include variables appropriate for diagnosing. In TSP, defoliation has remained severely high, on average 40-50%, on the pine trees in TSP. Insect attacks are likely important causes for the defoliation at TSP. Defoliation increased somewhat from 2000 to 2002, followed by a slight decrease to 2003. This increase may be due to the relative moist and favourable weather condition in 2003, as well as decreasing insect attacks. It should also be noted that concentrations of potentially toxic Al in the soil solution were highest in TSP, which may be an additional stress factor for the trees. The role of air pollution and possible changes in soil chemical properties on defoliation is difficult to assess. Direct influences of air pollution from local sources on crown condition was found in countries in Central and Eastern Europe but no effects from long-range transported sources were found (UN-ECE, 1997).

Defoliation responds to many stress factors and is therefore a valuable overall indicator for forest condition. Generally, stand age, site index, drought, insect and fungi attacks and air pollution are correlated with crown condition. It is, therefore, necessary to use multivariate statistical techniques, in order to eventually reveal relations between stress factors and tree crown condition.

3.5.2 Foliage discoloration

Foliage discoloration is an important indicator of crown condition. However, so far minor discoloration is observed within all species investigated and at all sites.

3.5.3 Foliage damage

Insect attack is a major defoliation cause on Masson pine, clearly documented in TSP in 2000. The insect defoliators have been Tussoch moths (*Dasychira axutha);* a pine caterpillar (*Dendrolimus* sp., possibly *pinidiatrea*); and a pine sawfly, possibly *Diprion pini*., all of which are feeding on the pine needles. In the crown assessments the amount of defoliation attributable to insect attacks is assessed. Assessing this from the ground with binoculars does not provide accurate figures, and will normally be low and careful estimates, depending strongly on the observer's confidence and experience about such insect damage. The site-average in TSP was 17.3%, 0.6%, 0.2% and 0.1% in 2000, 2001, 2002 and 2003 respectively, indicating a possibly clear reduction over time.

In CJT, another insect, the Masson-pine caterpillar *Dendrolimus punctatus* was frequent in 2002.

Table 9. The frequency of annual death (mortality) of dominant trees in each sites

site	Tree species	2000	2001	2002	2003
TSP	Masson pine	Start	6.13% (23/375)	1.99% (7/352)	0.27% (1/367)
LCG	Masson pine	Start	1.41% (4/283)	0% (0/279)	0.00% (0/278)
CJT	Masson pine		Start	10.2% (14/137)	13.97%(19/136)
CJT	Chinese fir		Start	0%	0%
LGS	Armandi pine		Start	1.10% (4/365)	2.13%(8/375)
LXH	Chinese fir		Start	0%	0%

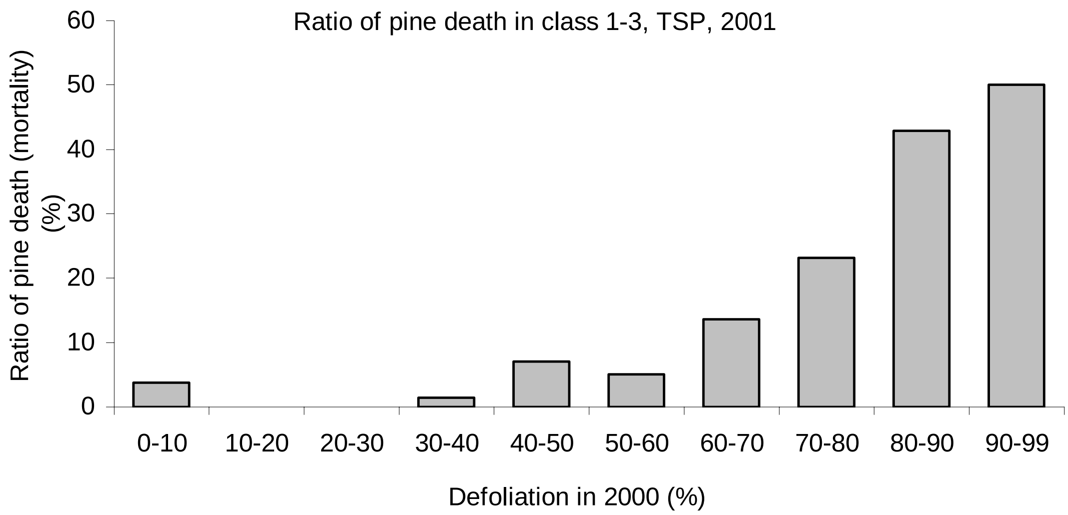

Figure 19. The Relationship between plot mean defoliation of dominant Masson pine trees in 2000 and mortality in 2001 in TSP.

3.5.4 Tree death (mortality)

Extremely high mortality was observed in TSP in 2001. A longhorn beetle, probably the Japanese Pine Sawyer (*Monochamus alternatus*), was abundant under bark on dying and dead trees, together with considerable amounts of coarse wood frass outside the bark. In the autumn of 2000, it was apparent that the attacked, but still living, trees were severely defoliated prior to the attacks by this bark living beetle larva. The frequency of annual death (mortality) of dominant trees is an important indicator of forest health. Therefore we compared the corresponding values in Table 9. It shows that the site TSP has higher mortality than LCG. It can be noted that this Longhorn beetle is responsible for spreading the Pine Wood Nematode (*Bursaphelenchus xylophilus)*, with its alarming attacks in Europe pine forests in the recent decade. However, as far as we know, this nematode is not present in the areas of the IMPACTS project.

In the relation between mortality of Masson pines in 2001 and defoliation in 2000 is presented. It shows that, the trees with a slight defoliation (10-25%) have very low death possibility; the trees with a moderate defoliation (25-60%) have an increasing but still lower death possibility; while the trees with a severe defoliation (>60%) have a very higher and very rapidly increasing death possibility.

3.5.5 Foliar chemistry

Foliar chemistry in 2003 was analyzed at the research sites CJT, LGS and LXH, whereas the latest data from the other research sites were collected in 2002. Values for current year foliage are reported in Table 10.

Elements that showed the largest differences between sites were N, P, S and Na. Foliar N concentrations ranged from 13 g kg^{-1} at TSP to 25 g kg^{-1} at LGS, whereas P concentrations ranged from 1.0 g kg^{-1} at TSP to 1.8 g kg^{-1} at LGS. Concentrations of S and Na were between 1.2 g S kg^{-1} (CJT) and 2.4 g S kg^{-1} (LCG), and 0.04 g Na kg^{-1} (LCG) and 0.4 g Na kg^{-1} (LXH), respectively. Foliar concentrations of K, Ca, Mg and Al did not show large differences between sites and were, averaged for all sites, 6 g K kg^{-1}, 4 g Ca kg^{-1}, 1 g Mg kg^{-1} and 0.2 g Al kg^{-1}.

The differences in needle content of N and S between the sites were not directly related to N and S deposition. Foliar S at TSP, that received by far the highest S-deposition of all sites, was lower than at LCG where S deposition was ca 25% of S deposition at TSP (Table 2). The high Na concentrations at LXH may be related to the proximity of the sea the higher deposition of seasalts compared with the other sites.

Foliar chemistry at CJT, LGS and LXH was fairly stable with time for all elements except for P and S at LXH (Figure 20). The cause for the decrease in P and increase in S in 2003 at LXH is not clear but might be related to phenological variation during the season, as LXH is a broadleaved stand.

The interpretation of the foliar chemistry is somewhat uncertain, as threshold values are not easily available for the actual tree species and growing conditions. Also, concerning broadleaved tree species at southern latitudes, as being the case in LXH, there might be seasonal effects on foliar chemistry, and this needs to be further clarified. However, given the available literature from Europe and China on thresholds concentrations and ratios between elements (Bonneau 1988; Hüttl 1991, Yan Chang-Rong et al. 1999, Zhang Ping et al. 1995, Appendix D) we have the following interpretation at present. In general, no deficiency symptoms are observed on the foliage, and no acute deficiency appears to be the case in the five catchments. Nitrogen concentrations are high. This is particularly the case for LGS, where N values have remained at the very high level of around 25 g/kg (Figure 21).

The nutritional status appears to be somewhat unbalanced, mainly due to the high nitrogen values (Table 12). This is the case for phosphorus, with N/P-ratios from 12 to 15, which is higher than for a balanced nutrition, having the ratio around 6-12. Phosphorus is also low in absolute concentrations in

TSP, being only slightly above a nutrient deficiency (Table 11**)**. Low phosphorus availability might stem from the formation of sparingly soluble calcium phosphates, resulting from the high loads of calcium and high pH. This may well be a widespread phenomenon in China. It is notable that the lowest P values were found in the severely damaged pine forest of TSP outside the city of Chongqing (Table 10). Also, in LGS the high nitrogen creates an unbalance towards potassium with ratios around 3.7. However, K values are themselves normal. Mg concentrations appear to be sufficient, and also well balanced in relation to nitrogen. Ca concentrations are high. However, Ca concentrations in foliage normally vary within wide limits without having any physiological effects on trees. Concerning the LXH catchment, with its broadleaf tree species, low N concentrations were seen. Further work is needed on linking foliar chemistry with site characteristics in order to provide appropriate interpretation of the results.

Table 12. Element content (g/kg) in current year foliage of main tree species in monitoring sites

Site	Tree species	Study year	Defoliation ratio	K	Na	Ca	Mg	Al	N	P	S
LCG	Masson pine	2000-2002	14%	7.06	0.04	4.19	1.12	0.20	14.47	1.18	2.42
TSP	Masson Pine	2000-2002	42%	5.72	0.05	4.03	1.30	0.18	13.44	0.99	2.00
CJT	Masson pine	2001-2002	24%	5.38	0.21	4.41	1.31	0.27	17.24	1.43	1.34
LGS	Armand pine	2001-2002	3%	6.61	0.17	4.36	1.67	0.27	25.34	1.88	1.84
CJT	Masson pine	2002-2003	4%	5.51	0.24	4.52	1.26	0.22	17.25	1.29	1.23
LGS	Armand pine	2002-2003	3%	6.71	0.20	4.37	1.56	0.22	24.90	1.70	1.62
LXH	broadleaves	2002-2003	5%	6.62	0.37	3.15	1.08	0.08	14.80	1.18	1.25

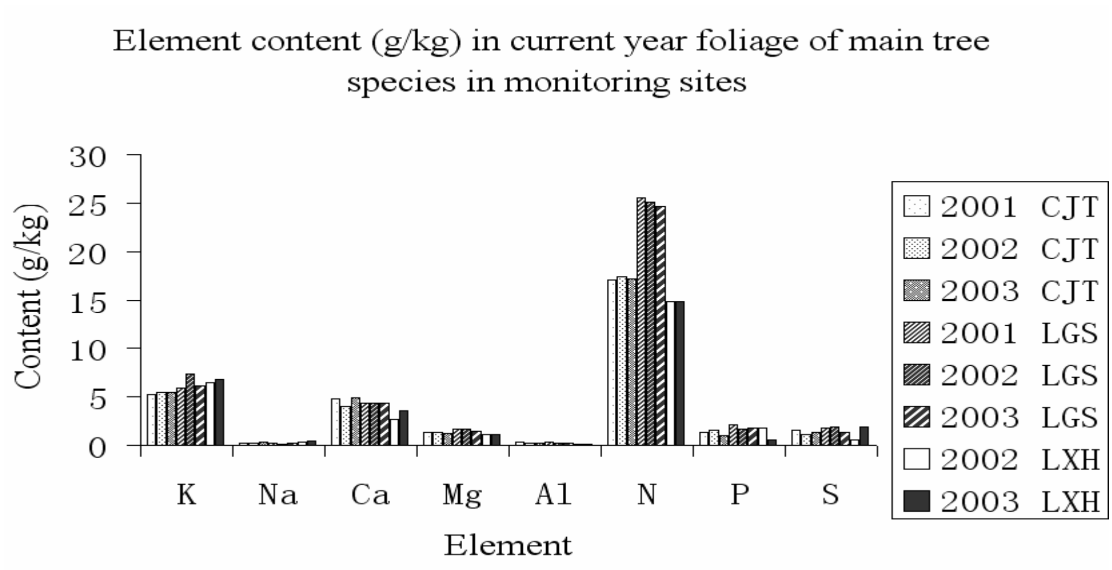

Figure 21. The elemental content in current year foliage of main tree species in catchments CJT, LGS and LXH in 2001, 2002 and 2003

Table 13. Foliar chemistry, reference values (g/kg) (Zhang Ping et al. (1995).

Site	Tree species	Study year	Tree health status	K	Na	Ca	Mg	Al	N	P	S
Jinyunshan, Chongqing	Masson pine	1993	Defoliation <10%	9.34	0.09	4.23	0.89	---	10.45	0.92	---
Nanshan, Chongqing	Masson pine	1993	Defoliation >60%, severely damaged by SO_2	7.05	0.11	7.10	1.15	---	12.06	0.72	---

3.6 Ground vegetation

Ground vegetation and biodiversity changes are monitored in permanent sample plots in all five catchments as described in the ground vegetation manual. A large set of indicators of environmental change is recorded; changes in species composition, species numbers of different plant groups and single species' abundances. These indicators enable early detection of changes in vegetation brought about by broad-scale, regional factors as air pollution as well as climatic change.

3.6.1 Biodiversity

Chinese forest ecosystems comprise a wide range of biodiversity variation. Thus species numbers vary considerably between and also within the catchments. The total number of species was equal or differed only slightly between the year of analyses and the reanalyses in three of the four analysed catchments. However, changes in plant biodiversity in these catchments occurred, as new species appeared and others disappeared.

The total number of species recorded in the 50 1-m^2 plots during the first reanalysis of plots varied from only 67 species in LCG to 175 species in LGS (Table 14). The total species number increased considerably in LGS from the first year of analyses to the first reanalysis two years later, possibly due to differences in phenology, as fieldwork was carried out two weeks earlier in 2003 than in 2001. For variation of species within each catchment, see Appendix C.

The great variation in plant diversity between catchments emphasizes the need for monitoring in more than 5 catchments in Chinese forest ecosystems. In order to study changes over time in different spatial scales, the total number of species in the 30x30m plots was recorded in the first reanalysis of each catchment.

Table 14. Total number of species recorded in the 5 catchments, at the first year of analysis and the first year of reanalysis.

Catchment	Year of first analyses	Year of first reanalysis	Total number of species in the 50 plots recorded the year of first analysis	Total number of species in the 50 plots recorded the year of first reanalysis	Total number of species in 50 1m^2 plots + ten 30x30m^2 plots, recorded at first reanalyses
LCG	2000	2002	67	67	171
TSP	2000	2002	65	61	147
LGS	2001	2003	137	175	285
CJT	2001	2003	78	78	127
LXH	2002	2004	154	(Not yet recorded)	(Not yet recorded)

3.6.2 Ground vegetation change

The ground vegetation data provide possibilities for testing several variables for ground vegetation and biodiversity changes that may be related to acid rain as well as climate variability. Changes in ground vegetation in LCG, TSP, LGS and CJT from establishment to the first re-analysis two years later were analysed by testing the hypothesis of no change (i.e. median change = 0, against the two-tailed alternative; Wilcoxon's test (see the ground vegetation manual). The parameters tested were:

- changes in species composition (as expressed by positions along ordination axes)
- changes in species number (α-diversity); total species number and numbers of different plant groups
- change in abundance for each species with observed abundance change in more than 5 plots.

Change in species composition

Significant changes in species composition between the year of establishment and the reanalysis were not observed along the most important vegetation gradient in any of the four catchments. However, along the second most important vegetation gradient significant changes were observed in two of the four reanalysed catchments (Table 15), possibly due to climatic and seasonal variation between the first year of analyses and the reanalyses two years later. Changes in species composition that can be related to acid rain were not expected at reanalyses performed only two years after the first year of analyses (the year of establishment of each catchment); thus continued monitoring is needed.

Univariate and multivariate statistical methods were used in order to detect changes in species composition between the year of establishment and year of reanalysis. The state of the art ordination method, DCA – Detrended Correspondence Analysis, was used to detect changes in species composition. No significant change in plot displacement along the main gradient (DCA 1) in any catchments at level P 0.05 was observed (Table 15, Figure 22 - Figure 25). Along DCA 2, a significant change in plot displacement was observed for both TSP (increased plot scores for 30 of the plots) and for LGS (decreased plot scores for 33 of the plots). In TSP, the vegetation gradient along DCA 2 is interpreted as due to variation in soil moisture (decreasing along the gradient), pH (increasing along the gradient) and tree influence (decreasing along the gradient). The most probable reason for the significant change is climatic variation; 30 plots have been displaced in the direction of sites with drier weather conditions. In LGS, the vegetation gradient along DCA 2 is interpreted as due to variation in soil moisture (decreasing along the axes) and micro-topographic terrain roughness (decreasing along the axes); i.e. 33 plots have been displaced in the direction of sites with higher soil moisture. In LGS the change may be due to both seasonal variation (different time for field work the in 2001 and in 2003) and climatic variation.

Table 15. Summary of Wilcoxon one-sample test of species composition change along DCA first two axes (P value given) in the 2-year study period for 4 of the 5 IMPACTS catchments. Wilcoxon tests of the hypothesis “no change” were made against the two one-tailed alternative hypotheses for all species composition with significance probabilities. Changes significant at level P 0.05 are indicated by bold face types. n = 50 (in CJT area, n=46). n – is number of plots with decreased and n+ is number of plots with increased DCA plot scores along the first and second DCA ordination axes, respectively.

Reference area	Years analysed	DCA 1 change				DCA 2 change			
		Mean change	n-	n+	P	Mean Change	n-	n+	P
LCG	2000-02	0.007	20	29	0.171	-0.009	25	24	0.762
TSP	2000-02	-0.038	30	20	0.067	**0.085**	**20**	**30**	**0.030**
LGS	2001-03	0.029	22	28	0.398	**-0.113**	**33**	**17**	**0.001**
CJT	2001-03	-0.039	27	19	0.199	0.032	18	28	0.438

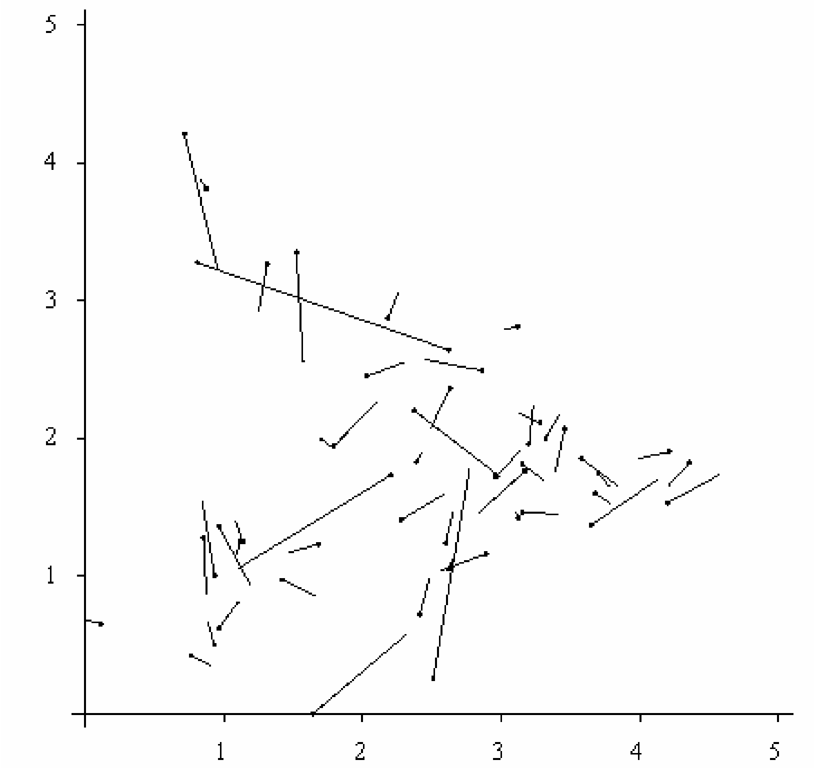

Figure 22. Plot displacement in DCA of 50 plots analysed in 2000 and 2002 in LCG (no turned).

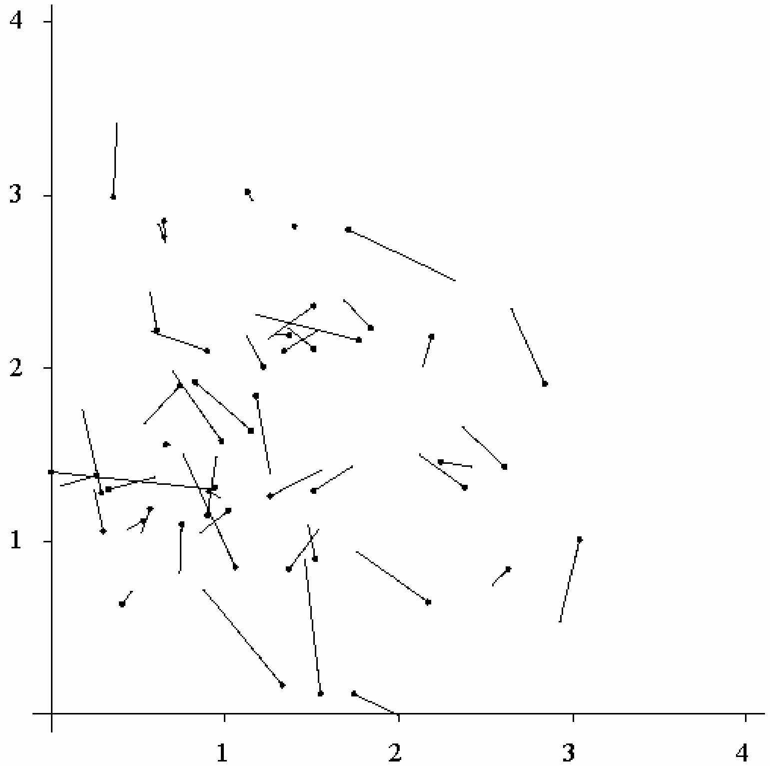

Figure 23. Plot displacement in DCA of 50 plots analysed in 2000 and 2002 in TSP (DCA1 and DCA2 turned).

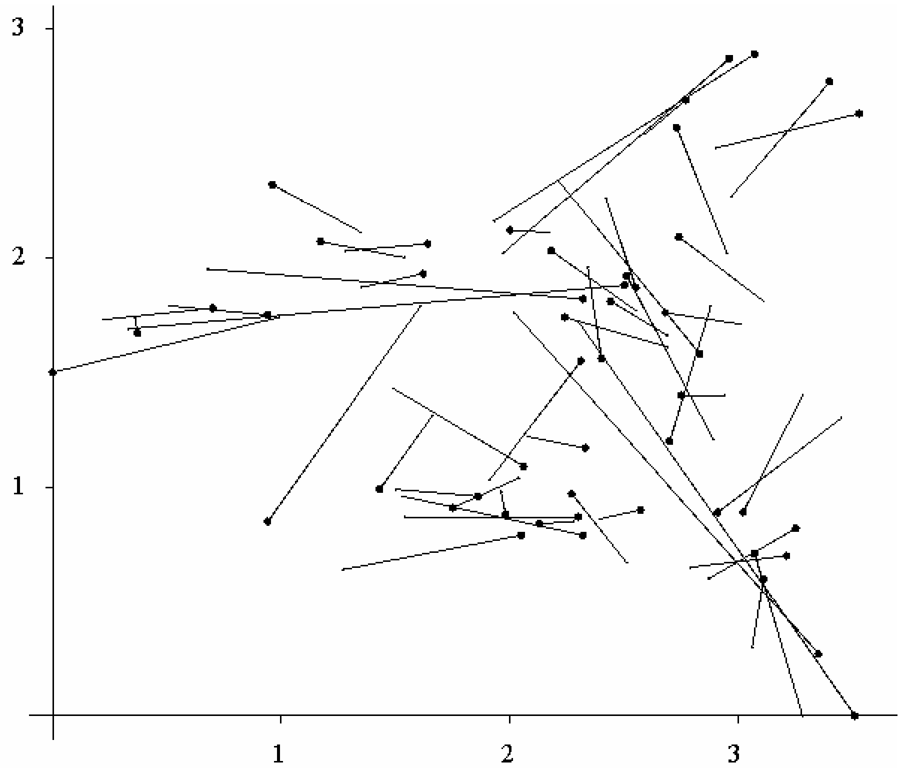

Figure 24. Plot displacement in DCA of 50 plots analysed in 2001 and 2003 in LGS (DCA2 turned).

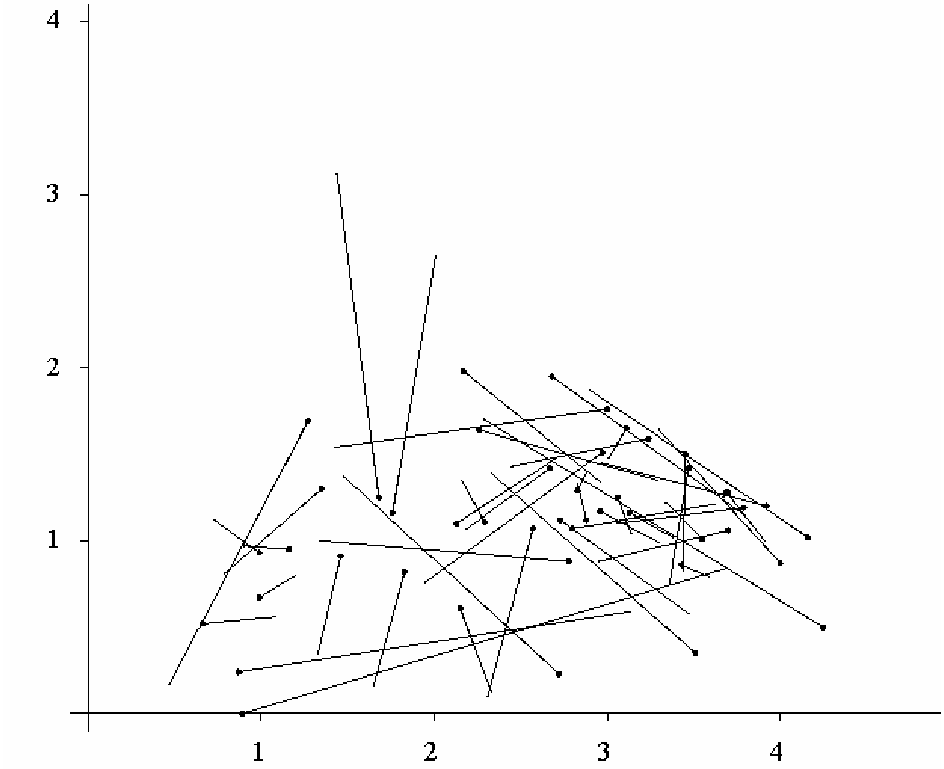

Figure 25. Plot displacement in DCA of 50 plots analysed in 2001 and 2003 in CJT (plots 4, 5, 30, 40 made passive, DCA2 turned).

Change in species diversity

The number of bryophyte species has changed significantly in all four catchments, most probably due climatic variation between the years of analyses. For the vascular plants significant change in species diversity was only observed in the LGS catchment.

The detailed ground vegetation monitoring provides data for testing biodiversity changes (Table 14) that may be related to environmental changes. The results from the Chinese forest ecosystems based on results from the first year of analysis and reanalysis two years later partly confirms the experiences from the Norwegian ground vegetation monitoring plots based on more than fifteen years of monitoring, i.e. that bryophytes respond very fast to climatic fluctuations.

In the 2-year study period, the total number of species per 1-m^2 plot decreased significantly (Table 16) in LCG (p=0.008) and TSP (p=0.005), while increased significantly in LGS (p<0.0001) and CJT (p=0.006). The average change was –0.68, -0.92, 5.8 and 0.82 species per plot respectively.

Vascular plant species number only increased significantly in LGS (Table 16; decrease was observed in one of the 50 plots, increase in 43 plots, p<0.0001). The average change in LGS was 4.0 species per plot.

The number of bryophyte species decreased significantly in LCG (p=0.015) and TSP (p=0.009), while increased significantly in LGS (p<0.0001) and CJT (p=0.006), The average change was -0.42, -0.38, 1.80 and 0.46 species per plot respectively.

Table 16. Change in species number per plot in each reference area during the two-year study period. Wilcoxon Signed Ranks tests (P value given) of the hypothesis 'Median change = 0' were made against the two-tailed alternative hypotheses for all combinations of area and plant group (decreasing species number is in italics; significant change in species number in bold-face types). n = 50. n – number of plots with decrease and n+: number of plots with increase in total species number, vascular plant number and bryophyte number, respectively.

Catch-ment	Years analysed	Mean change	Total number of species		P	Mean change	Vascular plant species		P	Mean change	Bryophyte species		P
			n -	**n +**			**n-**	**n+**			**n-**	**n+**	
LCG	2000-02	-0.68	***30***	***11***	***0.008***	-0.26	23	17	0.335	-0.42	***17***	***4***	***0.015***
TSP	2000-02	-0.92	***26***	***12***	***0.005***	-0.54	23	16	0.092	-0.38	***16***	***4***	***0.009***
LGS	2001-03	5.80	**2**	**47**	**<0.001**	4.00	**1**	**43**	**<0.001**	1.80	**7**	**33**	**<0.001**
CJT	2001-03	0.82	**11**	**24**	**0.006**	0.36	17	22	0.184	0.46	**6**	**20**	**0.006**

The decrease in bryophyte number in LCG and TSP may be due to a drier climate in 2002 than in 2000. However, the mean change in total species number is lower than the mean change in bryophyte number for both LCG and TSP, due to the decrease in vascular plant number (not significant at level p ≤ 0.05).

The increase in bryophyte number in LGS and CJT is probably due to more moist climate in 2003 than in 2001

The significant increase in vascular plant species in LGS is probably related to seasonal variation; the time point for analyses in 2001 and for reanalyses in 2003 differed by a few weeks.

Change in species abundances

Due to the short period between analysis and reanalysis of the catchments, significant changes in species abundances were not expected. However, some of the species have decreased and some others have increased. In two catchments the number of vascular species with a decrease was significantly higher than expected (Table 16, and Appendix Table C-7), while in the other two catchments the number of vascular species with an increase was higher. In one catchment the increase of vascular plant species abundances (18 species) is most probably due to seasonal and/or climatic variation. Some bryophyte species decreased in abundance in two catchments, while an increase was observed in one catchment only. The abundance changes recorded for bryophytes are most probably due to climatic variation.

In LCG the species abundance of two vascular plants (*Cayratia japonica* and *Rubus buergeri*) decreased significantly (more than expected by chance; G-tests in Table 17). Correspondingly, abundances of three vascular plant species (*Cinnamomum camphora*, *Pteridium aquilinum var.la.* and *Smilax china*) decreased significantly in TSP. In LGS, 18 vascular plant species (Appendix Table.C-7) increased significantly (G-test significant at level $P<0.0001$) and in CJT two species (*Dalbergia hupeana* and *Lophatherum gracile*) increased significantly (G-test significant at level $p < 0.05$), most probably due to better climatic conditions for plant growth in 2003 than in 2001, as well as seasonal variation (a different time for field work in 2001 and in 2003).

Table 17. Summary of Wilcoxon one-sample tests of single species' abundance change, and overall *G*-tests for each catchment plant group, in the 2-year study period for 4 of the 5 IMPACTS catchments. Wilcoxon tests of the hypothesis 'No change' was made against the two one-tailed alternative hypotheses for all single species, for which abundance change was recorded in 5 or more plots in an area. Tests are reported as significant if *P* 0.05. Overall *G*-tests of the hypothesis 'Number of species with significant change does not deviate from the expected number [which is 0.025 × (total number of species tested) for each of abundance decrease and abundance increase, against the one-tailed alternative hypotheses (larger than). Significant overall tests are indicated by bold-face types.

Catchment	Years analysed	Total number of species tested	Decrease in abundance			Increase in abundance		
			Number of significant tests	G	P	Number of significant tests	G	P
Vascular plants								
LCG	2000–02	**18**	***2***	***3.01***	***0.0414***	1	0.51	0.2376
TSP	2000–02	**27**	**3**	**4.51**	***0.0169***	2	1.76	0.0923
LGS	2001–03	43	2	0.65	0.2101	**18**	**75.60**	**<0.0001**
CJT	2001–03	19	1	0.45	0.2512	**2**	**2.83**	**0.0462**
Bryophytes								
LCG	2000–02	10	1	1.33	0.1244	0	0.51	0.7624
TSP	2000–02	5	***2***	***8.18***	***0.0021***	0	0.25	0.6915
LGS	2001–03	17	0	0.86	0.8231	**4**	**11.62**	**0.0003**
CJT	2001–03	11	0	0.56	0.7729	0	0.56	0.7729

Two bryophyte species (*Leucobryum bowringii* and *Taxiphyllum subarcuatum*) decreased significantly in abundance in TSP, while four bryophyte species (*Isopterygium albescens, Lejeuna flava, Leucobryum juniperoideum* and *Metzgeria darjeelingensis*) increased significantly in abundance in LGS (G-test significant at level $P=0.0003$). In LCG and TSP, no bryophyte species increased in abundance and only one and two species decreased (not significantly), respectively. In LGS, no bryophytes species decreased. In CJT no bryophyte species decreased or increased significantly. The abundance decrease in TSP is probably due to the drier season in 2002 than in 2000, since bryophytes are sensitive to climate fluctuations and climate change (Potter et al., 1995; Callaghan et al., 1997; R. Økland, 1997; T. Økland et al., 2001, 2004), while the abundance increase in LGS may be both due to moister climate in 2003 than in 2001 as well as difference in time-point for field analyses in 2001 and 2003.

Final remarks regarding ground vegetation

The first reanalyses of ground vegetation in the LCG, TSP, LGS and CJT catchments were performed only two years after establishment analyses. However, significant results for ground vegetation and biodiversity changes were found. The results clearly show that bryophytes are good indicators of biotic effects of climatic fluctuations.

Experiences from other parts of the world show that vascular plants are good indicators for identifying long-term effects of acid rain and soil acidification. Thus, data from longer time periods are needed to identify vegetation changes that may be related to soil acidification or direct effects of air pollutants.

The optimised frequency for vegetation monitoring (e.g. two, three or five years) is not yet known for the Chinese forest ecosystems, and should be tested.

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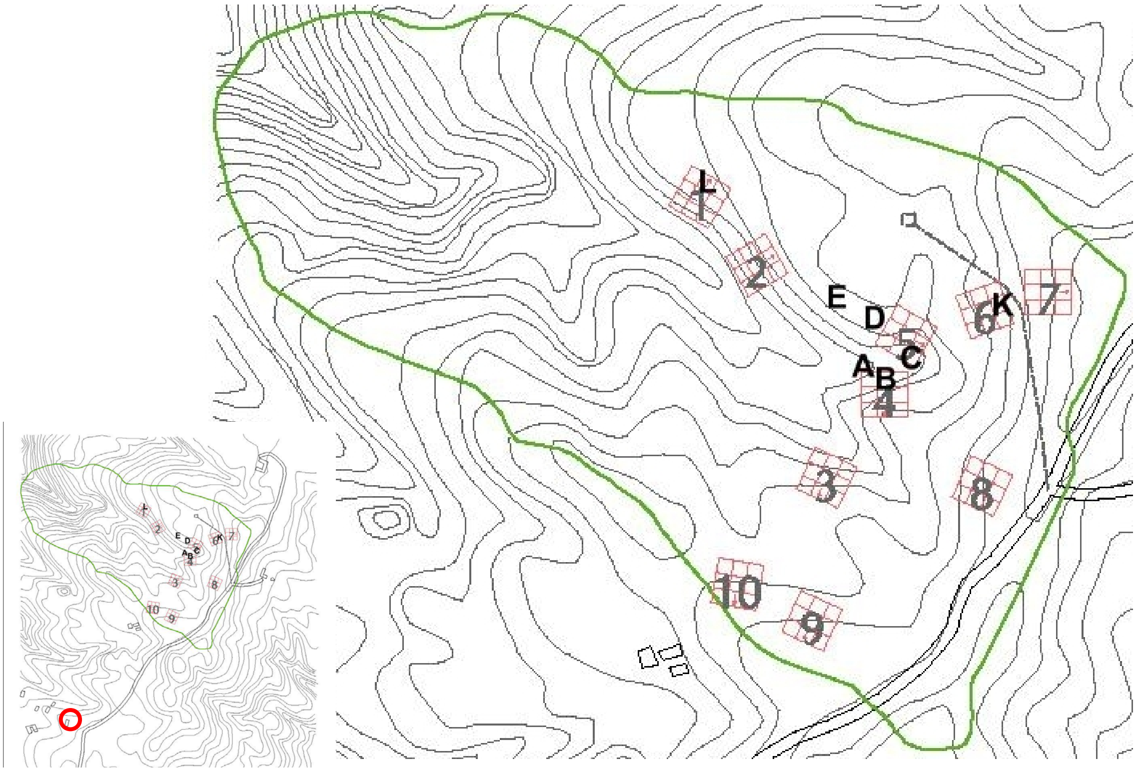
Appendices

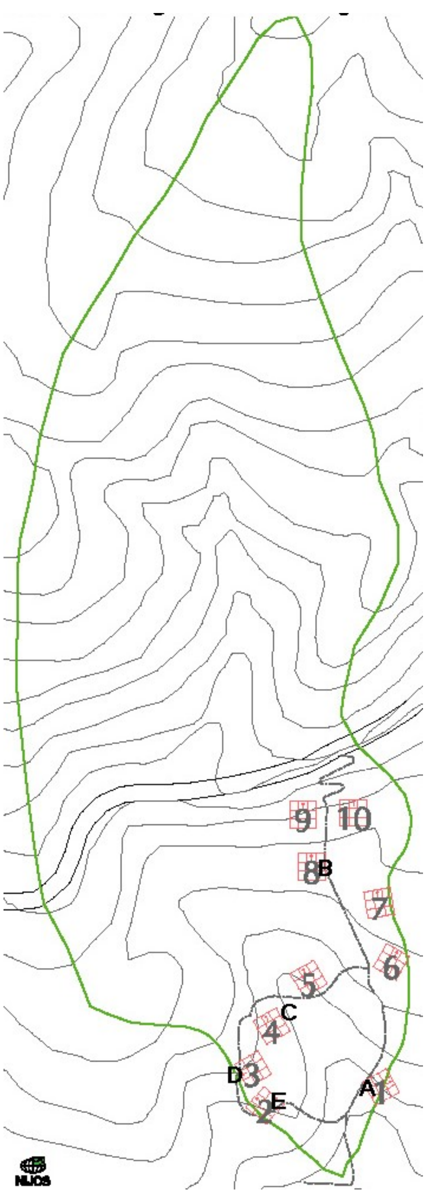
Appendix A. Maps of the monitoring sites

Tie Shan Ping (TSP)



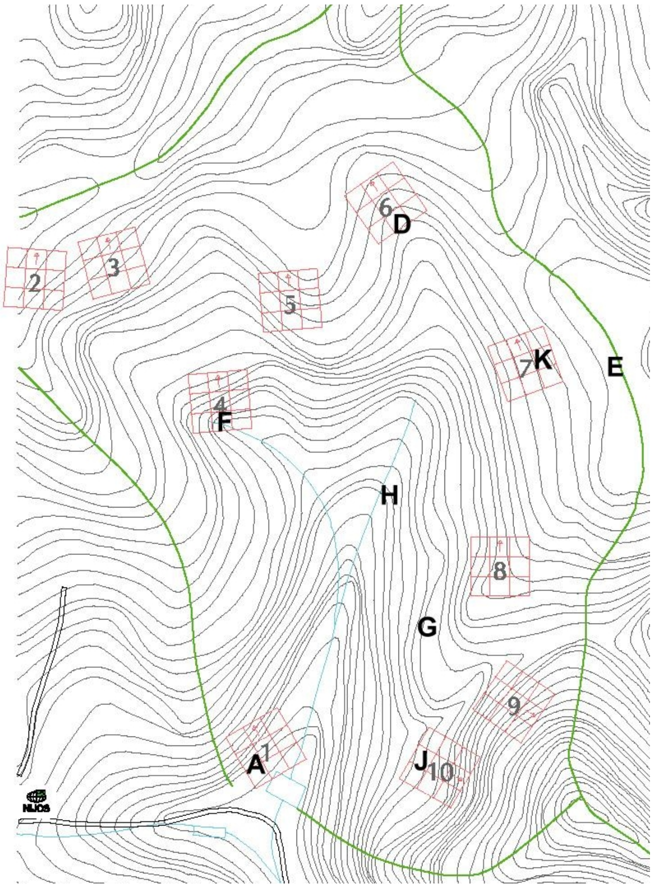
Map of the TSP catchment with monitoring and sampling locations indicated.

Lei Gong Shan (LGS)



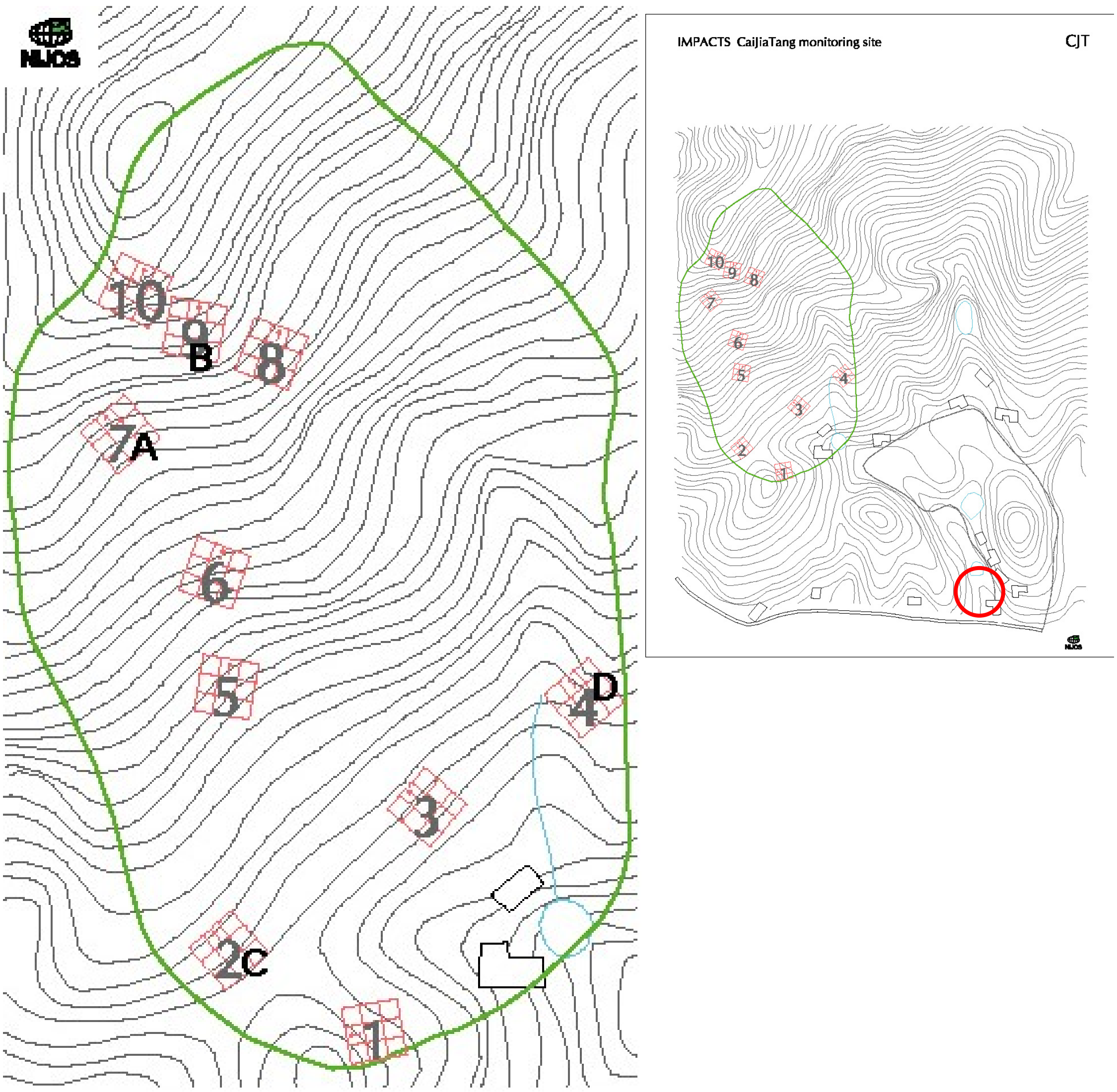
Map of the LGS catchment with monitoring and sampling locations indicated.

Liu Chon Guang (LCG)



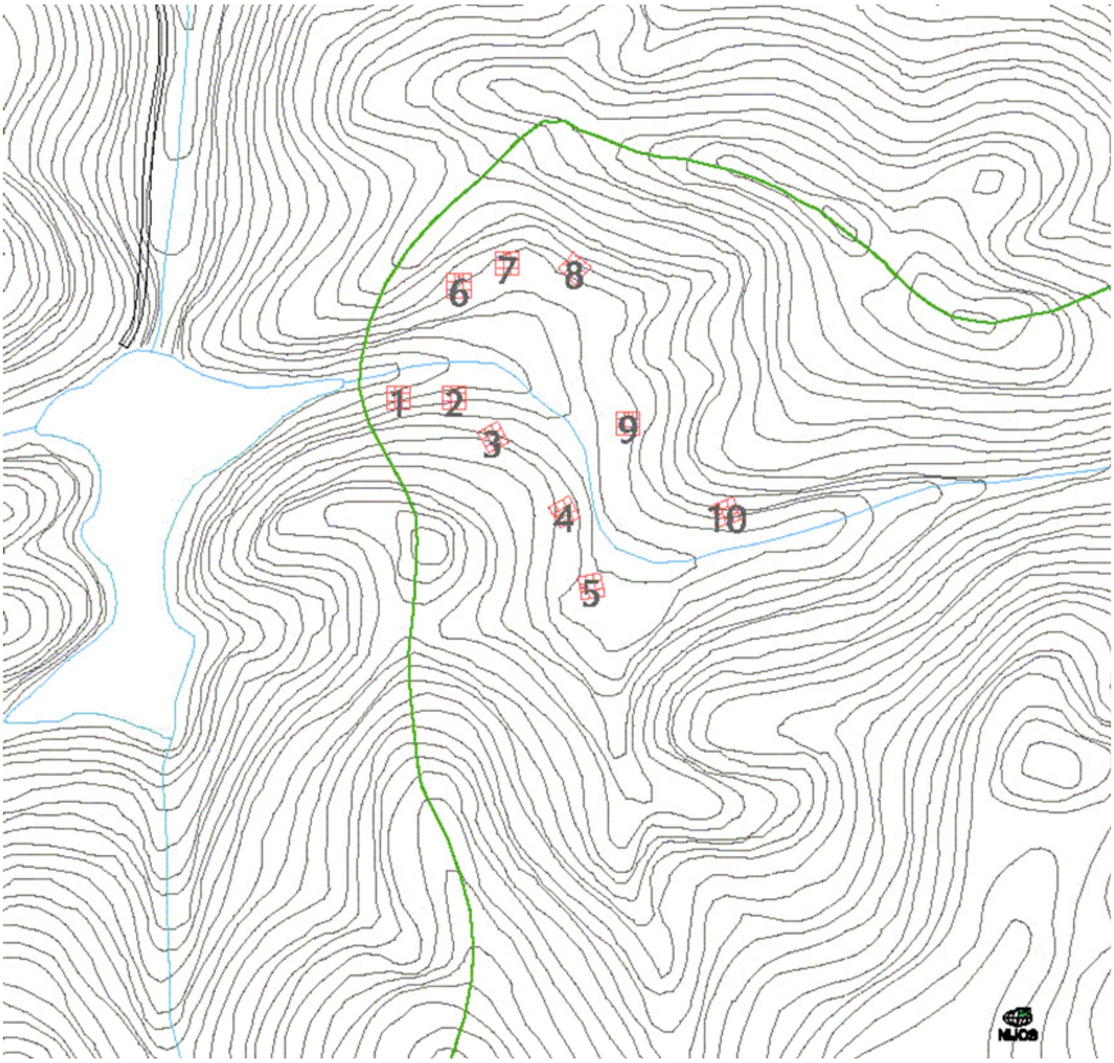
Map of the LCG catchment with monitoring and sampling locations indicated.

Cai Jia Tang (CJT)



Map of the CJT catchment with monitoring and sampling locations indicated.

Liu Xi He (LXH)



Map of the LXH catchment with monitoring and sampling locations indicated.

Appendix B. Annual chemical data for monitoring samples and chemical data for soils

Table B.1 Volume weighted average concentrations of all samples. The data for 2001 and 2002 are sample averages, while data for 2003 are calculated as average values of plot averages.

Tie Shan Ping

			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	NH_4^{+}	Ali	SO_4^{2-}	NO_3^{-}	Cl^{-}	tot-F	Alo	Tot-N	Tot-P	H_4SiO_4	Alk (pH corr)
	mm	pH	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µM	µg/L	µg/L	mg/L	µeq/L
2001																	
WO	782	4.13	59	15	3	10	92		201	35	13	4					0.02
BP	959	4.17	132	24	9	15	124		287	54	22	9					0.39
CTF	845	3.87	500	112	14	131	217	73	1024	73	71	21	5.6	4674	32	1.5	0.15
FTF	698	3.93	637	177	16	202	250	79	1226	87	110	24	7.9	5458	28	2.7	0.99
Stream	325	4.92	374	206	58	22	0.6	35	522	71	80	6	0.7	1235	2	8.7	3.66
2002																	
WO	1250	4.20	43	13	2	10	73		156	30	11	6					0.02
BP	1558	4.26	96	18	6	13	90		212	45	17	7					0.09
CTF	1381	3.87	376	86	10	99	129	67	766	58	59	18	2.4	3022	14	1.0	0.72
FTF	1096	4.00	475	119	11	151	176	81	897	79	86	19	3.0	4118	23	1.7	5.12
Stream	760	4.48	408	208	49	20	0.1	87	645	101	84	11	0.7	1508	3	9.2	0.32
2003																	
WO	1053	4.10	58	8.9	2.9	8.4	76		184	35	11	4.5					0.92
BP	1169	4.14	134	15	9.3	13	108		270	55	17	8.4					0.56
CTF	1059	3.76	558	88	10	123	161	88	985	65	60	19	2.6	3775	7.2	1.6	12
FTF	887	3.91	673	118	13	171	230	88	1126	101	84	22	2.9	5316	30	2.2	81
Soil0	516	3.90	1063	221	20	278	259	229	1623	375	133	25	20	9791	18	5.4	1.15
Stream	480	4.70	376	174	57	19	1.7	59	555	66	78	7.8	0.3	1021	1.6	8.4	1.04

Liu Chon Guang

			Ca^{2+}	Mg^{2+}	Na^+	K^+	NH_4^+	Ali	SO_4^{2-}	NO_3^-	Cl^-	tot-F	Alo	Tot-N	Tot-P	H_4SiO_4	Alk (pH corr)
	mm	pH	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µM	µg/L	µg/L	mg/L	µeq/L
2001*																	
WO	328	4.55	107	42	7	9	52		182	14	42	8					6.24
BP	407	4.85	139	53	7	10	43		191	11	47	13					14.32
CTF	204	4.28	305	89	9	94	48	18	562	31	40	29		1166	58	0.2	26.78
FTF	308	4.65	551	184	14	138	56	16	835	53	100	46		2203	121	0.4	35.34
2002																	
WO	678	4.54	130	24	6	10	54		201	18	10	9					16.38
BP	1080	5.14	218	41	14	21	64		274	36	19	12					32.69
CTF	397	4.29	528	126	19	126	47	23	795	24	34	26	2.0	1361	21	0.3	26.95
FTF	476	4.39	588	171	19	131	61	20	883	27	69	33	2.5	1368	20	0.5	33.62
2003																	
WO	403	4.89	155	38	7.7	18	51		255	18	7.2	8.3					13
BP	621	4.81	260	54	29	23	96		403	30	26	14					28
CTF	247	4.08	683	147	21	166	66	35	1089	34	39	36	3.3	2325	87	0.48	37
FTF	283	4.74	496	125	25	157	71	22	799	27	32	25	2.4	2228	100	0.58	60
Soil0	87	4.17	1212	304	23	333	86	113	1804	138	71	81	16	4949	124	2.6	8.4
Stream#	14	4.30	931	368	30	61	20	26	1147	16	25	11	1.5	1336	48	4.6	319

* The precipitation amount in LCG in 2001 does not include December.

Runoff data missing from February to June. Data are presented as average values

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			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	NH_4^{+}	Ali	SO_4^{2-}	NO_3^{-}	Cl^{-}	tot-F	Alo	Tot-N	Tot-P	H_4SiO_4	Alk (pH corr)
	mm	pH	μeq/L	μeq/L	μeq/L	μeq/L	μeq/L	μeq/L	μeq/L	μeq/L	μeq/L	μeq/L	μM	μg/L	μg/L	mg/L	μeq/L
2001*																	
WO	1081	5.17	209	44	6	4	14		52	8	75	2					128
BP	1271	5.01	145	35	7	5	18		79	6	57	3					80
FTF	571	6.07	304	64	9	79	4		125	42	64	5				0.1	269
2002																	
WO	1687	4.97	89	8	7	5	28		43	11	7	0.9					73
BP	2208	5.25	89	10	12	6	25		45	12	7	1.0					61
CTF	712	5.26	78	23	7	50	15	0.8	70	8	15	2	0.4	494	47	0.1	49
FTF	972	5.47	108	24	11	55	24	0.7	85	8	23	3	0.5	1568	70	0.1	79
Stream	1637	6.72	104	21	69	4	1.4		36	20	10	1	0.04	496	25	7.2	137
2003																	
WO	1001	4.44	25	5.1	2.9	4.1	33		75	26	3.6	1.1					2.9
BP	1368	4.63	27	4.9	5.2	3.8	29		68	18	5.2	1.1					5.4
CTF	879	5.05	91	26	9.3	62	26	2.7	133	21	18	3.0	0.65	1236	50	0.09	28
FTF	975	5.21	93	26	10	58	27	1.7	118	21	17	2.2	0.61	1282	53	0.12	47
Soil0	400	4.86	347	86	9.2	124	47	10	122	287	37	1.8	4.2	5945	220	0.32	55
Stream	908	6.55	50	21	80	4.3	0.9	0.00	36	24	6.0	0.62	0.10	522	36	7.4	88

*The precipitation in LGS in 2001 does not include January, February, June and December, no chemical analysis for October and November. CTF was not measured in 2001.

Caj Jia Tang

			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	NH_4^{+}	Ali	SO_4^{2-}	NO_3^{-}	Cl^{-}	tot-F	Alo	Tot-N	Tot-P	H_4SiO_4	Alk (pH corr)
	Mm	pH	μeq/L	μeq/L	μeq/L	μeq/L	μeq/L	μeq/L	μeq/L	μeq/L	μeq/L	μeq/L	μM	μg/L	μg/L	mg/L	μeq/L
2001																	
WO*	947	4.41	67	22	11	8	81		128	33	14	6					11
CTF	893	5.25	230	51	9	85	112	7	261	73	51	16	0.9	3138	140	2.4	61
FTF	971	5.29	312	84	19	124	198	3	375	94	71	21	1.4	4898	363	3.2	79
Stream	479	6.46	218	155	30	10	7	0.02	158	35	22	8	0.3	941	31	14.4	199
2002																	
WO	1611	4.47	41	12	6	7	56		102	31	7	5					2
CTF	1381	5.29	216	46	13	74	112	9	296	71	41	12	1.1	3148	107	0.7	65
FTF	1168	5.23	296	73	16	104	136	7	385	92	57	17	1.4	3993	154	1.5	75
Stream	293	6.66	207	157	34	7	0.1	0.0	157	57	23	6	0.0	867	43	14.2	165
2003																	
WO	1196	4.30	35	8.9	5.9	8.1	108		155	55	9.5	5.4					3.1
CTF	1161	4.88	275	46	11	84	173	11	381	95	44	17	0.6	4403	131	1.1	89
FTF	1003	5.16	379	69	16	127	195	9.4	496	120	68	21	0.9	5660	154	2.1	128
Soil0	1018	4.76	574	170	13	187	191	58	621	348	98	23	6.3	8949	274	5.4	57
Stream#	94	6.84	248	163	30	7.5	0.46	0.00	167	34	17	4.9	0.00	643	37	14	202

*The precipitation amount is underestimated because of overflow of the wet-only collector in May and June

Runoff data missing from February to June. Data are presented as average values

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			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	NH_4^{+}	Ali	SO_4^{2-}	NO_3^{-}	Cl^{-}	Tot-F	Alo	Tot-N	Tot-P	H_4SiO_4	Alk (pH corr)
	mm	pH	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µM	µg/L	µg/L	mg/L	µeq/L
2002																	
WO	1253	4.39	61	32	32	14	23		60	28	22	7					0.3
CTF	382	4.95	38	24	13	214	14	4	97	44	117	5	2.9	979	0.1	1.5	53
FTF	1654	4.86	91	47	21	59	28	5	93	36	43	5	4.1	1700	0.1	1.0	10
2003																	
WO	1197	4.62	59	16	33	9	26		88	12	26	5.6					0.00
BP	1843	4.59	44	8	32	13	14		94	8.6	17	5.4					5.4
CTF	1759	5.38	56	27	15	165	22	7.0	156	17	60	7.0	2.5	1564	0.07	0.7	33
FTF	1734	5.10	57	25	16	101	36	5.4	162	18	52	7.6	3.7	1950	0.07	1.0	30
Soil0	461	4.92	189	75	20	172	51	16	214	77	71	8.1	6.2	4116	0.13	1.4	22
Stream*	NA	6.61	27	8.1	62	19	4.6	0.00	35	3.1	22	11	0.00	220	0.06	14	80

* No data for runoff amount. Data are presented as average values.

Table B.2 annual median concentrations with 10 and 90-percentiles in parenthesis of major chemical components. Only samples that are determined for all major anions and cations (i.e. contributing significantly to the charge balance: Ca, Mg, Na, K, SO4, NO3, Tot-F and Ali) are used in the calculation.

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TSP	N	pH	UV	Colour	Ali	Alo	Ca2+	Mg2+	Na+	K+	NH4+	SO42-	NO3-	Cl-	tot-F	Alkalinity	Tot-N	Tot-P	H4SiO4
2001			E254nm	mg Pt L-1	µmol L-1	µmol L-1	µeq L-1	µeq L-1	µeq L-1	µeq L-1	µeq L-1	µeq L-1	µeq L-1	µeq L-1	µeq L-1	µeq L-1	µg L-1	µg L-1	mg L-1
WO	43	4.12 (3.82-4.52)	0*	0*	0*	0*	74.4 (29.3-230)	17.2 (5.43-47.5)	4.35 (0.88-22.4)	11.5 (5.14-39.8)	115 (54.9-341)	241 (127-581)	41.8 (21.7-118)	17.0 (7.36-40.0)	6.32 (1.48-21.7)	0*	ND	ND	0*
BP	43	4.26 (3.86-5.84)	0*	0*	0*	0*	169 (64.9-568)	26.7 (13.0-71.3)	8.96 (2.04-49.9)	17.6 (6.44-56.2)	132 (64.6-407)	331 (154-845)	61.4 (28.6-189)	19.5 (9.10-65.5)	9.47 (2.83-29.9)	0.00 (0.00-3.12)	ND	ND	0*
CTF	46	3.96 (3.30-5.26)	0.264 (0.173-0.456)	14.5 (8.93-25.5)	40.1 (13.0-98.6)	5.19 (1.85 -14.1)	617 (262-1704)	138 (68.8-265)	15.7 (3.95-54.8)	153 (85.9-292)	215 (146-467)	1301 (594-2930)	73.1 (45.9-245)	82.1 (41.5-206)	22.4 (11.0-69.5)	0*	4930 (2808-8873)	10.0 (4.3-37)	1.54 (0.90-2.46)
FTF	82	4.04 (3.17-5.74)	0.305 (0.202-0.514)	18.0 (10.7-33.4)	42.4 (11.2-131)	6.86 (2.22-24.4)	776 (277-1989)	186 (105-383)	16.3 (5.02-75.0)	210 (104-402)	245 (137-496)	1526 (6723-3406)	88.7 (50.6-315)	122 (66.5-247)	26.8 (12.5-92.5)	0.00 (0.00-2.44)	5900 (3340-11650)	20.0 (8.2-56)	2.85 (1.58-4.09)
L0	52	4.21 (3.46-5.59)	0.870 (0.206-1.284)	57.7 (10.3-96.5)	110 (23.4-471)	29.84 (10.86-73.7)	1784 (751-3777)	457 (197-817)	30.9 (8.70-84.3)	462 (245-849)	437 (73.6-1126)	2815 (1189-6158)	403 (167-846)	242 (108-500)	38.7 (15.6-102)	0.00 (0.00-1.60)	13715 (7466-24740)	20.0 (6.0-53)	7.98 (3.05-17.5)
L1	84	3.91 (3.57-4.75)	0.210 (0.032-0.538)	10.6 (0.00-40.0)	193 (33.4-508)	20.01 (1.56-46.2)	549 (333-1639)	360 (178-509)	31.0 (14.5-54.3)	78.4 (9.68-266)	0.00 (0.00-17.6)	121 (557-2464)	440 (172-1630)	99.1 (51.7-244)	25.1 (11.6-55.6)	0*	6160 (2488-21728)	4.0 (0.0-18)	20.90 (12.72-38.5)
L2	80	4.12 (3.87-4.73)	0.091 (0.024-0.219)	2.60 (0.00-10.1)	172 (28.5-667)	13.71 (1.31-44.9)	452 (247-992)	279 (147-409)	32.3 (12.1-58.2)	45.6 (6.10-530)	0.00 (0.00-6.16)	907 (379-2184)	412 (194-1092)	86.7 (53.5-227)	16.7 (9.72-47.2)	0*	5970 (2404-16340)	2.0 (0.0-14)	18.20 (13.67-30.6)
L3	45	4.09 (3.94-4.47)	0.063 (0.040-0.106)	0.52 (0.00-2.41)	297 (38.8-371)	18.53 (4.17-33.4)	499 (196-1583)	202 (143-299)	26.0 (13.2-47.1)	35.3 (5.95-387)	0.00 (0.00-10.3)	1424 (490-2220)	277 (151-1159)	85.2 (38.5-187)	25.2 (14.4-37.3)	0*	3710 (2148-16468)	1.0 (0.0-13)	16.60 (11.96-27.7)
L4	40	4.02 (3.84-4.55)	0.053 (0.023-0.082)	0.00 (0.00-1.87)	282 (45.5-569)	20.57 (6.23-47.6)	593 (199-1511)	196 (127-306)	22.7 (15.1-44.1)	19.9 (6.64-180)	0.00 (0.00-7.27)	1358 (472-2463)	249 (173-1389)	96.7 (57.9-204)	38.5 (12.0-56.9)	0*	3950 (2446-19540)	2.0 (0.0-17)	16.00 (10.99-29.4)
SW	53	4.94 (4.72-5.28)	0.021 (0.008-0.050)	0.00 (0.00-0.00)	16.9 (9.09-27.4)	0.52 (0.00-2.97)	368 (323-531)	188 (160-247)	64.1 (44.2-95.8)	21.5 (17.1-31.5)	0.00 (0.00-4.95)	507 (445-764)	62.7 (35.9-113)	89.5 (59.8-123)	6.37 (4.97-8.40)	0.00 (0.00-16.1)	970 (605-1724)	1.0 (0.0-14)	8.79 (7.42-10.5)
2002																			
WO	42	4.22 (3.68-4.63)	0*	0*	0*	0*	48.7 (24.2-184)	15.7 (2.51-53.1)	2.22 (0.00-31.0)	11.0 (3.71-40.5)	91.3 (26.7-335)	176 (84.5-734)	40.9 (16.1-148)	12.6 (5.70-55.4)	6.32 (1.58-25.2)	0*	ND	ND	0*
BP	44	4.19 (3.62-4.95)	0*	0*	0*	0*	144 (41.8-850)	22.2 (5.43-114)	7.39 (1.87-61.3)	14.3 (5.96-85.7)	119 (24.9-572)	252 (102-1400)	61.0 (18.1-333)	21.9 (8.74-102)	10.5 (3.16-54.6)	0*	ND	ND	0*
CTF	52	3.97 (3.02-5.14)	0.279 (0.101-0.536)	12.3 (2.28-27.5)	37.8 (10.4-156)	3.32 (0.00-13.23)	486 (171-1894)	109 (43.8-435)	12.2 (0.04-58.9)	135 (46.4-260)	148 (74.2-345)	900 (375-4084)	68.5 (26.0-275)	85.3 (27.9-230)	18.4 (6.84-104)	0*	3675 (1460-9626)	9.0 (5.0-40)	1.20 (0.45-2.99)
FTF	90	4.27 (3.02-5.89)	0.292 (0.119-0.688)	16.0 (3.95-38.2)	30.4 (2.65-330)	3.71 (0.11-22.4)	557 (173-2749)	138 (53.4-603)	17.0 (1.74-64.7)	186 (75.4-505)	213 (96.3-526)	1012 (386-6163)	84.7 (32.5-343)	116 (40.0-273)	21.1 (7.84-111)	0*	4710 (2034-13028)	16.0 (6.8-106)	1.76 (0.87-5.07)
L0	51	4.12 (3.76-4.76)	0.777 (0.158-1.157)	62.4 (4.30-93.2)	74.8 (23.3-517)	14.08 (4.45-70.8)	1036 (472-3877)	248 (90.5-1051)	18.4 (2.61-94.0)	289 (102-672)	241 (30.5-743)	1554 (615-6260)	356 (148-996)	161 (44.0-504)	26.3 (11.6-104)	0*	10870 (3830-25860)	17.0 (6.0-54)	4.84 (2.05-16.7)
L1	90	3.99 (3.66-4.63)	0.185 (0.030-0.607)	7.40 (0.00-47.7)	178 (41.0-471)	9.08 (0.87-35.6)	461 (193-1635)	306 (150-436)	29.1 (11.3-54.9)	37.3 (9.18-182)	0.00 (0.00-3.91)	963 (533-2512)	341 (118-1223)	84.1 (36.4-153)	20.0 (11.0-49.1)	0*	5130 (2208-17520)	4.0 (0.0-8.1)	18.0 (13.31-49.4)
L2	84	4.19 (3.77-4.68)	0.097 (0.029-0.248)	0.00 (0.00-8.25)	162 (34.2-527)	5.56 (0.75-29.6)	381 (145-641)	277 (116-363)	32.0 (10.4-56.0)	30.6 (4.86-113)	0.00 (0.00-0.00)	967 (351-2349)	245 (30.1-500)	79.8 (39.6-148)	17.6 (8.42-32.5)	0*	3480 (462-7012)	3.5 (0.0-6.0)	18.8 (12.29-44.1)
L3	47	4.02 (3.87-4.50)	0.076 (0.043-0.124)	0.00 (0.00-0.94)	329 (144-643)	9.27 (2.42-23.1)	517 (206-1089)	197 (140-387)	22.6 (12.0-41.8)	49.4 (10.7-256)	0.00 (0.00-0.00)	1502 (782-2824)	356 (153-1060)	72.8 (46.4-178)	24.2 (12.1-37.3)	0*	4780 (2435-14950)	2.0 (0.0-6.0)	15.5 (12.39-41.6)
L4	43	4.07 (3.91-4.76)	0.054 (0.030-0.086)	0.00 (0.00-0.07)	312 (19.2-569)	8.90 (0.07-27.7)	537 (167-1284)	186 (152-322)	29.6 (18.4-48.6)	15.9 (5.06-160)	0.00 (0.00-0.00)	1423 (457-2513)	306 (29.6-951)	71.6 (47.7-180)	33.7 (10.2-49.4)	0*	4300 (734-14030)	4.0 (0.0-9.0)	14.2 (12.70-29.2)
SW	52	4.71 (4.42-4.94)	0.033 (0.018-0.066)	0.00 (0.00-0.00)	29.0 (20.0-46.1)	0.41 (0.00-2.29)	396 (334-557)	200 (159-241)	52.6 (44.8-89.5)	19.9 (15.6-29.1)	0.00 (0.00-2.21)	607 (514-781)	77.0 (43.7-127)	84.1 (66.1-138)	8.45 (5.64-12.0)	0*	1150 (743-1955)	3.0 (0.0-8.0)	8.83 (6.93-10.6)
2003																			
WO	43	4.09 (3.70-4.82)	0*	0*	0*	0*	69.4 (20.6-275)	11.5 (2.47-36.5)	4.35 (0.00-18.4)	12.0 (2.56-34.4)	91.4 (11.9-241)	233 (93.2-519)	40.0 (12.3-114)	12.7 (3.67-35.0)	5.26 (0.21-16.6)	0*	ND	ND	0*
BP	43	4.18 (3.62-4.80)	0*	0*	0*	0*	179 (44.5-1012)	21.4 (4.94-102.83)	11.7 (2.00-65.4)	16.6 (4.96-73.0)	126 (24.6-507)	341 (138-1503)	69.3 (22.2-334)	19.7 (7.95-84.3)	11.0 (3.74-59.5)	0*	ND	ND	0*
CTF	51	3.57 (3.02-4.92)	0.32 (0.12-0.62)	17.6 (7.20-28.8)	119 (13.6-389)	5.37 (0.00-16.6)	818 (247-2125)	128 (41.1-347)	10.4 (2.61-70.5)	177 (58.6-367)	222 (52.2-485)	1411 (377-4005)	98.0 (23.2-373)	87.4 (22.3-205)	27.9 (8.21-95.8)	0*	5390 (1640-14390)	9.00 (0.00-32.0)	1.91 (1.03-3.77)
FTF	91	4.17 (3.07-6.78)	0.32 (0.16-0.64)	18.6 (10.0-34.7)	98.0 (0.00-689)	5.56 (0.00-20.5)	1020 (239-2815)	150 (55.1-555)	13.5 (3.48-87.0)	227 (73.1-565)	282. (102-793)	1574 (463-5389)	143 (42.1-561)	112 (34.4-389)	29.5 (7.32-129)	0*	6900 (2480-20940)	26.0 (1.30-141)	2.49 (1.31-5.89)
L0	45	4.00 (3.53-4.58)	0.94 (0.18-1.34)	60.50 (9.38-93.4)	225 (70.2-1051)	23.4 (5.11-57.1)	1467 (574-5654)	363 (104-1146)	23.49 (4.70-106)	452 (114-947)	198 (23.5-1156)	2489 (641-8210)	447 (184-1097)	206 (32.9-697)	30.0 (10.2-94.5)	0*	13630 (4730-27022)	13.0 (1.00-64.0)	6.77 (2.25-22.1)
L1	83	4.05 (3.79-4.56)	0.14 (0.03-0.35)	7.60 (0.00-20.1)	464 (118-1301)	11.9 (1.32-40.0)	480 (256-2257)	315 (173-448)	34.80 (17.1-68.9)	25.6 (5.37-342)	0.00 (0.00-11.0)	1006 (606-2958)	341 (199-1471)	94.8 (46.5-226)	21.6 (13.7-48.9)	0*	4990 (2854-21628)	1.00 (0.00-8.00)	19.3 (13.1-48.9)
L2	58	4.08 (3.68-4.53)	0.09 (0.01-0.21)	3.20 (0.00-7.44)	448 (93.5-1610)	7.23 (0.45-40.3)	416 (249-616)	291 (170-375)	41.10 (15.0-60.0)	18.7 (4.09-59.0)	0.00 (0.00-3.96)	1009 (497-2711)	241 (57.7-632)	82.4 (52.0-179)	19.2 (10.2-55.1)	0*	3470 (465-8943)	0.00 (0.00-4.00)	18.0 (12.9-52.3)
L3	42	4.11 (3.79-4.73)	0.07 (0.04-0.09)	1.40 (0.00-4.00)	853 (113-1473)	15.34 (4.24-44.3)	539 (291-1830)	216 (136-398)	28.5 (15.3-51.3)	64.7 (6.93-226)	0.00 (0.00-8.58)	1395 (498-2961)	417 (104-1393)	89.7 (58.8-192)	25.0 (11.1-37.1)	0*	6270 (1899-20334)	1.00 (0.00-4.60)	18.2 (13.2-40.4)
L4	41	4.03 (3.75-4.43)	0.06 (0.04-0.09)	0.75 (0.00-2.90)	903 (465-1527)	18.0 (5.49-40.9)	397 (150-1360)	181 (146-426)	33.9 (21.3-55.2)	35.3 (7.42-153)	0.00 (0.00-5.57)	1625 (536-2537)	225 (51.8-1260)	67.7 (38.6-125)	33.2 (15.3-49.0)	0*	3390 (1279-17994)	0.00 (0.00-6.80)	16.4 (12.1-37.7)
SW	52	4.73 (4.55-4.88)	0.02 (0.01-0.03)	0.00 (0.00-0.78)	55.7 (40.2-80.1)	0.00 (0.00-1.03)	371 (348-401)	173 (159-196)	56.6 (45.7-71.7)	19.1 (16.1-22.2)	0.00 (0.00-5.38)	546 (520-603)	62.4 (38.8-100)	75.9 (58.1-106)	6.76 (4.74-11.5)	0*	927 (625-1439)	0.00 (0.00-4.00)	8.05 (6.45-10.5)

* denotes assumed data. Measured values for Ali and Alkalinity are set to 0 in the statistical calculation when pH was above 5.5 and below 5.0, respectively.

Liu Chong Guan,

LCG	N	pH	UV	Colour	Ali	Alo	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	NH_4^{+}	SO_4^{2-}	NO_3^{-}	Cl^{-}	tot-F	Alkalinity	Tot-N	Tot-P	H_4SiO_4
2001			E254nm	mg Pt L^{-1}	μmol L^{-1}	μmol L^{-1}	μeq L^{-1}	μeq L^{-1}	μeq L^{-1}	μeq L^{-1}	μeq L^{-1}	μeq L^{-1}	μeq L^{-1}	μeq L^{-1}	μeq L^{-1}	μeq L^{-1}	μg L^{-1}	μg L^{-1}	mg L^{-1}
WO	26	4.47 (4.15-6.23)	0*	0*	0*	0*	129 (30.6-288)	32.1 (11.4-114)	7.96 (3.15-16.4)	10.3 (4.02-20.7)	35.3 (15.7-106)	218 (86.6-452)	12.3 (3.98-42.5)	28.7 (5.13-114)	8.76 (4.63-17.6)	0.00 (0.00-30.7)	ND	ND	0*
BP	25	5.30 (4.42-6.56)	0*	0*	0*	0*	189 (30.7-405)	51.2 (24.0-128)	8.48 (3.88-22.6)	12.0 (3.78-34.2)	41.0 (19.0-158)	248 (68.3-638)	14.4 (3.45-44.7)	41.3 (9.62-81.2)	8.90 (4.16-34.2)	11.9 (0.00-72.4)	ND	ND	0*
CTF	24	4.42 (3.91-6.78)	0.111 (0.059-0.185)	13.00 (8.84-25.1)	7.74 (0.00-21.8)	0.00 (0.00-0.93)	295 (95.6-967)	83.3 (42.3-236)	9.63 (4.83-21.1)	87.2 (33.5-242)	35.9 (1.93-107)	564 (173-1538)	7.78 (2.04-109)	34.2 (13.3-91.4)	25.2 (7.18-41.7)	0.00 (0.00-130)	831 (360-2103)	60.2 (11.5-148)	0.30 (0.00-0.72)
FTF	67	5.43 (4.05-6.42)	0.154 (0.083-0.397)	27.30 (10.8-61.0)	7.39 (0.00-23.8)	0.00 (0.00-1.04)	539 (138-1676)	150 (61.2-480)	12.0 (5.38-41.3)	146 (65.9-394)	43.4 (1.98-170)	858 (217-2291)	31.5 (7.17-195)	63.3 (21.9-261)	30.8 (9.04-98.4)	30.6 (0.00-150)	1934 (506-4232)	86.2 (38.3-211)	0.34 (0.00-0.96)
L0	9	3.85 (3.60-4.55)	1.392 (0.950-2.178)	165.00 (51.0-212)	41.8 (12.2-144)	10.90 (0.53-21.8)	1481 (426-2285)	320 (96.9-617)	29.4 (10.3-66.2)	232 (60.0-461)	13.5 (3.43-130)	2415 (556-3537)	16.6 (3.41-169)	137 (33.7-193)	90.8 (34.4-214)	0.00 (0.00-9.34)	1185 (374-5303)	101.2 (16.1-335)	2.98 (0.88-14.4)
L1	23	4.28 (3.84-4.66)	0.210 (0.123-0.487)	18.20 (7.80-50.7)	117 (24.2-196)	2.30 (0.00-12.0)	641 (352-1091)	250 (125-440)	20.1 (10.3-40.7)	69.5 (23.1-235)	6.28 (0.00-12.1)	1143 (568-2044)	33.6 (9.56-165)	130 (49.3-262)	31.2 (14.6-92.9)	0*	674 (178-4979)	28.8 (7.0-138)	12.94 (3.72-17.1)
L2	52	4.19 (3.92-4.80)	0.063 (0.024-0.240)	7.80 (1.33-20.5)	122 (19.8-266)	2.30 (0.00-11.2)	500 (290-1017)	192 (98.2-417)	14.5 (7.45-37.0)	42.5 (11.1-154)	2.86 (0.00-9.07)	1110 (591-1879)	10.9 (1.97-318)	88.5 (25.0-327)	28.7 (15.4-64.4)	0*	413 (80-6300)	17.0 (9.8-139)	11.20 (0.00-17.2)
L3	30	4.35 (3.91-4.79)	0.043 (0.022-0.126)	5.20 (0.00-10.4)	161 (38.7-353)	2.67 (0.00-10.3)	622 (388.5-855)	256 (116-566)	21.3 (7.95-40.1)	36.1 (10.4-68.5)	0.79 (0.00-12.4)	1268 (783-1953)	19.8 (1.12-300)	100 (30.0-275)	38.8 (17.8-64.9)	0*	894 (96-6885)	13.1 (3.2-47.4)	11.57 (0.45-16.7)
L4	21	4.32 (4.09-4.74)	0.031 (0.022-0.064)	2.50 (0.00-6.50)	77.4 (16.7-176)	1.48 (0.00-7.41)	528 (308-888)	245 (73.6-499)	19.2 (7.13-36.2)	53.3 (27.1-79.8)	2.64 (0.00-5.57)	940 (674-1499)	55.7 (3.55-210)	73.8 (20.4-425)	18.3 (16.4-22.9)	0*	926 (46-4549)	27.8 (9.4-136)	6.90 (1.89-12.9)
SW	58	4.59 (4.41-4.90)	0.016 (0.010-0.028)	2.50 (0.00-6.00)	17.0 (8.74-25.7)	0.00 (0.00-1.08)	528 (317-710)	371 (212-635)	35.4 (25.8-48.3)	36.7 (28.6-49.8)	3.36 (0.00-11.7)	957 (701-1498)	9.39 (3.81-20.0)	57.1 (19.3-150)	8.87 (6.05-13.2)	0*	309 (87-1008)	13.6 (3.8-192)	7.10 (0.00-14.2)
2002																			
WO	30	5.01 (4.17-6.43)	0*	0*	0*	0*	178 (30.3-480)	34.3 (12.8-77.0)	9.31 (1.56-17.7)	11.8 (4.41-28.3)	67.3 (14.2-240)	245 (74.5-645)	22.9 (6.99-45.2)	10.7 (4.48-21.1)	9.21 (2.67-26.9)	0.00 (0.00-103)	ND	ND	0*
BP	35	5.88 (4.91-6.74)	0*	0*	0*	0*	323 (109-944)	48.3 (20.5-116)	20.9 (6.05-58.2)	15.2 (8.80-47.7)	48.5 (6.04-195)	390 (122-1090)	41.3 (17.2-101)	22.1 (10.0-75.2)	14.6 (4.37-46.1)	16.6 (0.00-151)	ND	ND	0*
CTF	36	4.65 (3.66-5.79)	0.189 (0.069-0.331)	17.3 (9.08-36.9)	11.0 (1.43-40.8)	1.91 (0.56-10.1)	601 (142-1969)	126 (32.2-469)	15.3 (5.65-72.4)	100 (28.9-429)	47.9 (23.5-113)	815 (206-3297)	22.7 (10.4-63.0)	28.9 (9.90-95.8)	25.2 (4.53-93.2)	0.00 (0.00-91.0)	1473 (728-2627)	1.2 (0.0-98.0)	0.25 (0.02-0.95)
FTF	70	5.01 (3.98-6.11)	0.156 (0.077-0.390)	21.6 (9.47-54.7)	7.91 (0.00-33.3)	1.93 (0.63-7.61)	494 (168-2442)	159 (38.0-597)	18.7 (5.42-63.1)	116 (35.5-411)	55.7 (16.1-238)	880 (227-3720)	23.0 (7.66-85.1)	37.4 (10.9-122)	30.1 (6.95-152)	0.00 (0.00-125)	1656 (698-3965)	1.6 (0.0-220)	(0.37 0.00-1.08)
L0	23	4.07 (3.89-4.71)	1.220 (0.743-1.400)	162 (98.0-231)	64.8 (22.9-140)	22.1 (16.83-33.6)	1320 (498-3500)	298 (88.8-917)	17.8 (7.16-73.3)	274 (79.6-929)	78.9 (8.7-300)	1472 (524-5373)	49.5 (4.5-313)	82.6 (13.9-215)	74.7 (21.5-174)	0*	3181 (1416-9534)	1.1 (0.1-89.5)	1.32 (0.44-5.04)
L1	22	4.20 (3.71-4.54)	0.122 (0.041-0.352)	8.33 (1.42-43.0)	72.6 (28.6-161)	12.3 (4.15-22.3)	392 (239-972)	147 (67.6-341)	16.4 (7.67-33.3)	50.3 (14.8-95.5)	3.61 (0.01-13.2)	940 (643-1710)	8.35 (0.00-89.6)	39.2 (13.1-105)	16.7 (9.02-64.7)	0*	267 (58-2118)	1.5 (0.0-30.9)	3.10 (0.00-6.62)
L2	40	4.27 (3.92-4.70)	0.087 (0.028-0.218)	4.73 (0.00-23.0)	60.9 (27.2-138)	8.78 (3.47-20.0)	544 (255-1367)	179 (85.6-360)	18.8 (8.19-28.9)	50.2 (27.1-137)	1.80 (0.00-13.6)	1041 (498-1691)	12.3 (0.00-364)	31.9 (13.6-83.7)	17.3 (8.43-67.5)	0*	410 (27-5166)	3.9 (0.0-36.5)	1.97 (0.00-8.82)
L3	28	4.25 (3.85-4.79)	0.075 (0.025-0.162)	5.36 (0.00-15.6)	79.1 (27.4-246)	11.7 (4.76-22.3)	478 (270-892)	159 (81.0-349)	15.6 (8.47-31.8)	46.5 (11.1-169)	1.21 (0.00-6.45)	1103 (617-1594)	7.34 (0.00-145)	34.2 (16.1-74.5)	20.8 (10.4-49.1)	0*	249 (0-1860)	3.4 (0.0-38.5)	2.56 (0.00-7.43)
L4	15	4.42 (3.96-4.74)	0.027 (0.015-0.073)	1.42 (0.00-8.57)	39.4 (21.4-80.4)	4.45 (3.28-9.43)	638 (287-876)	243 (101-31)	23.0 (7.82-29.0)	58.3 (29.3-85.9)	0.50 (0.00-7.91)	1087 (853-1465)	5.07 (0.00-8.87)	19.2 (9.50-48.6)	15.6 (11.5-18.0)	0*	68 (0-331)	4.4 (0.0-33.8)	1.88 (0.00-6.22)
SW	47	4.52 (4.36-4.80)	0.022 (0.014-0.034)	2.03 (0.00-3.81)	20.3 (9.57-31.9)	1.78 (0.50-3.11)	569 (415-800)	312 (252-566)	29.5 (23.5-35.8)	38.8 (34.1-45.3)	0.00 (0.00-4.84)	1003 (870-1497)	6.93 (2.30-21.6)	25.5 (22.1-35)	9.69 (6.05-15.5)	0*	136 (0-503)	0.0 (0.0-15.1)	5.31 (0.14-6.75)
2003																			
WO	27	5.13 (4.37-6.05)	0*	0*	0*	0*	194 (79.4-344)	43.9 (16.7-144)	7.83 (2.78-17.1)	12.8 (4.25-42.2)	37.8 (2.28-147)	284 (129-649)	16.4 (0.00-65.2)	6.77 (3.67-18.3)	6.26 (1.79-27.0)	3.39 (0.00-48.8)	ND	ND	0*
BP	38	5.94 (4.18-6.47)	0*	0*	0*	0*	252 (98.1-628)	34.6 (19.3-115)	27.2 (5.78-98.0)	22.4 (8.18-82.6)	105 (41.3-283)	367 (141-1010)	30.70 (13.0-85.0)	27.4 (4.39-123)	15.2 (5.98-50.9)	34.2 (0.00-74.8)	ND	ND	0*
CTF	39	4.91 (3.72-6.00)	0.17 (0.10-0.58)	26.4 (12.8-91.1)	22.8 (0.00-175)	2.15 (0.87-14.7)	510 (231-2344)	114 (54.4-495)	12.2 (8.09-73.3)	133 (55.9-433)	48.6 (0.66-188)	803 (341-3811)	23.9 (4.75-108)	25.4 (11.1-141)	23.8 (10.8-110)	0.00 (0.00-119)	1851 (847-6617)	73.5 (33.0-227)	0.42 (0.21-1.28)
FTF	87	5.35 (3.99-6.45)	0.19 (0.10-0.59)	31.0 (12.0-76.6)	15.5 (0.00-149)	2.97 (0.99-11.0)	611 (212-2224)	152 (51.5-512)	18.7 (8.70-102)	179 (66.3-495)	80.2 (15.8-280)	999 (355-3390)	24.1 (6.00-127)	37.0 (10.8-181)	30.9 (8.93-112)	28.9 (0.00-157)	2618 (1279-6602)	97.0 (25.8-259)	0.43 (0.14-1.74)
L0	30	4.12 (3.71-4.86)	1.39 (0.80-2.11)	242 (157-399)	113 (61.3-289)	17.0 (10.4-36.2)	1476 (686-2559)	345 (136-671)	25.9 (12.9-47.6)	297 (185-797)	50.6 (3.90-181)	1998 (1080-3745)	15.8 (2.50-501)	89.6 (38.4-181)	54.1 (34.8-90.7)	0*	2839 (1946-12358)	82.5 (43.3-353)	2.66 (0.87-5.08)
L1	21	4.49 (4.04-4.91)	0.06 (0.01-0.27)	0.00 (0.00-29.4)	114 (33.9-231)	8.71 (2.45-17.4)	655 (357-868)	211 (97.9-345)	15.7 (10.0-39.6)	66.0 (35.6-116)	0.29 (0.00-6.71)	1127 (717-1508)	59.7 (0.00-216)	21.7 (9.31-48.0)	18.1 (7.05-56.3)	0*	976 (334-3182)	29.0 (18.9-44.4)	3.98 (0.60-8.89)
L2	26	4.37 (3.97-4.54)	0.03 (0.02-0.19)	2.10 (0.00-21.7)	119 (67.1-398)	6.30 (2.59-15.6)	534 (190-1074)	204.84 (58.8-350)	14.8 (9.13-37.0)	71.6 (27.1-95.1)	0.14 (0.00-2.32)	1090 (511-2485)	17.9 (0.00-239)	28.4 (13.1-47.0)	15.3 (5.55-65.1)	0*	1268 (153-6680)	29.0 (12.0-42.0)	4.23 (1.31-7.30)
L3	23	4.37 (4.21-4.63)	0.03 (0.02-0.06)	2.50 (0.00-5.97)	119 (60.5-246)	7.19 (2.73-12.5)	518 (181-827)	203 (53.5-325)	22.6 (7.44-39.9)	44.2 (9.16-77.6)	0.14 (0.01-8.07)	1080 (564-1458)	5.92 (0.00-202)	29.6 (10.2-52.9)	15.3 (7.53-48.6)	0*	562 (226-3478)	22.0 (10.0-32.1)	2.88 (1.09-6.10)
L4	9	4.60 (4.25-5.10)	0.02 (0.01-0.04)	0.50 (0.00-4.96)	59.8 (11.3-241)	3.19 (0.82-5.77)	814 (256-897)	340 (55.3-383)	34.8 (8.26-39.8)	28.4 (24.9-52.0)	0.14 (0.00-1.97)	1272 (718-1416)	0.00 (0.00-61.0)	30.2 (6.60-32.4)	4.90 (0.56-12.0)	0*	475 (57.5-1803)	21.5 (14.4-31.1)	3.14 (1.68-5.28)
SW	42	4.63 (3.71-7.53)	0.03 (0.01-0.15)	2.50 (0.00-25.40)	12.15 (0.00-75.0)	1.32 (0.26-3.31)	551 (289-2427)	348 (78.3-554)	31.5 (8.11-46.9)	45.1 (25.7-127)	2.53 (0.08-69.0)	1199 (481-1476)	8.14 (0.00-35.5)	22.3 (11.7-39.2)	9.55 (2.45-17.9)	0*	970 (396-2497)	32.7 (14.9-110)	5.59 (0.70-6.29)

* denotes assumed data. Measured values for Al_i and Alkalinity are set to 0 in the statistical calculation when pH was above 5.5 and below 5.0, respectively. Stream water data are from three sampling sites.

Cai Jia Tang

CJT	N	pH	UV	Colour	Ali	Alo	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	NH_4^{+}	SO_4^{2-}	NO_3^{-}	Cl^{-}	tot-F	Alkalinity	Tot-N	Tot-P	H_4SiO_4
2001			E254nm	mg Pt L^{-1}	μmol L^{-1}	μmol L^{-1}	μeq L^{-1}	μeq L^{-1}	μeq L^{-1}	μeq L^{-1}	μeq L^{-1}	μeq L^{-1}	μeq L^{-1}	μeq L^{-1}	μeq L^{-1}	μeq L^{-1}	μg L^{-1}	μg L^{-1}	mg L^{-1}
WO	33	4.75 (3.99-6.50)	0*	0*	0*	0*	58.9 (35.6-168)	14.8 (0.00-41.8)	10.0 (3.95-26.0)	9.2 (3.12-25.0)	85.7 (23.6-212)	141 (75.4-351)	40.3 (12.3-86.8)	11.6 (6.01-37.6)	8.03 (2.84-15.3)	0.00 (0.00-57.6)	ND	ND	0*
BP	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CTF	40	6.08 (4.66-6.90)	0.200 (0.100-0.631)	75.7 (35.8-198)	0.00 (0.00-13.3)	0.74 (0.07-4.07)	197 (101-790)	56.4 (28.0-247)	10.0 (3.04-46.8)	83.0 (49.3-414)	129 (64.1-438)	274 (115-1221)	87.5 (27.1-287)	49.6 (17.0-169)	16.1 (9.42-64.3)	33.5 (0.00-162)	3460 (1872-7898)	113 (55.1-364)	1.83 (0.68-4.55)
FTF	48	6.33 (4.81-7.04)	0.291 (0.110-0.835)	100 (38.4-272)	0.00 (0.00-7.13)	1.13 (0.34-4.94)	322 (147-758)	76.1 (41.7-308)	21.7 (6.33-53.3)	121 (62.5-576)	214 (99.7-581)	390 (156-1357)	86.0 (39.8-376)	69.5 (30.1-301)	21.1 (10.4-66.3)	45.1 (0.00-184)	5740 (2586-10588)	196 (82.1-688)	2.65 (1.40-5.63)
L0	38	5.61 (4.84-6.23)	0.600 (0.351-1.738)	177.00 (102-527)	0.00 (0.00-21.5)	3.13 (0.70-10.8)	402 (169-858)	137 (50.7-283)	13.0 (4.09-31.8)	149 (73.6-693)	196 (63.6-412)	536 (151-1333)	202 (90.6-648)	60.6 (22.6-233)	21.3 (10.5-54.0)	45.1 (0.00-70.6)	6720 (3068-11492)	169 (66.3-451)	5.93 (3.22-9.39)
L1	11	4.79 (4.55-5.06)	0.116 (0.078-0.431)	24.40 (12.5-81.3)	8.52 (3.39-25.3)	2.27 (1.41-2.71)	399 (282-825)	136 (111-378)	21.7 (8.53-40.5)	35.8 (4.45-122)	5.71 (0.00-42.8)	468 (245-855)	67.8 (28.6-357)	52.7 (21.9-115)	15.8 (13.7-26.8)	0*	1920 (1064-5300)	15.0 (1.8-83.6)	4.76 (4.28-12.3)
L2	16	4.99 (4.53-5.96)	0.061 (0.041-0.161)	15.67 (6.18-35.9)	24.7 (0.00-29.9)	4.33 (1.13-5.43)	411 (310-853)	160 (91.4-252)	20.4 (11.7-53.5)	42.2 (6.14-88.1)	0.00 (0.00-29.6)	649 (329-1117)	154 (33.2-339)	44.5 (9.87-90.7)	15.8 (10.5-42.4)	0.00 (0.00-8.36)	2950 (737-5711)	16.2 (2.9-24.6)	8.85 (4.13-15.3)
L3	17	4.78 (4.25-6.05)	0.053 (0.023-0.090)	10.76 (5.87-38.0)	23.2 (0.00-32.6)	1.24 (0.43-3.85)	469 (258-1152)	119 (95.9-207)	23.1 (11.9-49.1)	12.8 (7.67-22.2)	0.00 (0.00-11.0)	687 (246-1350)	177 (56.0-507)	40.1 (15.2-134)	23.4 (10.1-63.2)	0.00 (0.00-8.32)	5500 (982-9392)	15.9 (2.5-25.9)	11.2 (8.63-14.2)
L4	13	4.52 (4.19-6.54)	0.039 (0.030-0.056)	9.67 (4.54-13.5)	24.1 (0.00-31.4)	1.76 (1.08-9.62)	599 (281-811)	167 (90.2-261)	27.0 (17.4-48.4)	8.18 (4.09-24.7)	0.00 (0.00-8.00)	740 (189-1467)	386 (82.2-670)	48.8 (23.0-147)	46.3 (13.1-73.4)	0.00 (0.00-33.1)	8280 (4802-10010)	10.4 (0.8-23.6)	12.4 (10.5-23.7)
SW	48	6.95 (6.65-7.18)	0.016 (0.000-0.029)	9.25 (4.76-15.8)	0*	0.16 (0.00-0.59)	221 (184-280)	165 (120-220)	27.7 (16.7-40.6)	8.45 (5.24-14.3)	0.00 (0.00-17.5)	165 (108-202)	16.4 (4.06-56.6)	18.1 (13.8-27.3)	7.90 (1.58-11.3)	213 (168-265)	440 (114-1396)	31.0 (14.0-47.4)	14.5 (13.3-15.8)
2002																			
WO	43	4.51 (4.05-5.37)	0*	0*	0*	0*	47.9 (16.3-100)	13.2 (5.63-23.1)	6.48 (0.93-16.9)	7.24 (2.87-19.4)	60.8 (29.2-184)	120 (65.6-269)	39.6 (12.1-114)	9.84 (3.40-19.7)	5.42 (3.12-10.8)	0.00 (0.00-5.80)	ND	ND	0*
BP	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CTF	48	5.87 (4.50-6.51)	0.159 (0.071-0.263)	79.3 (29.4-189)	0.00 (0.00-30.0)	1.83 (0.12-3.67)	282 (91.4-573)	55.8 (26.6-109)	15.2 (5.53-34.1)	79.3 (40.3-161)	132 (75.0-217)	432 (151-878)	97.4 (30.1-234)	47.3 (16.1-115)	14.6 (6.17-32.2)	41.3 (0.00-158)	4240 (1859-6330)	94.0 (50.3-208)	0.75 (0.37-1.32)
FTF	52	6.06 (4.57-6.62)	0.221 (0.106-0.426)	122 (39.8-220)	0.00 (0.00-20.8)	2.67 (0.00-4.38)	378 (141-735)	76.1 (36.5-202)	14.7 (6.32-43.8)	109 (52.7-234)	143 (87.5-283)	453 (193-1169)	93.1 (37.3-286)	61.5 (19.3-150)	19.0 (7.65-44.0)	61.5 (0.00-178)	4235 (2375-8343)	135 (74.7-245)	1.35 (0.65-2.33)
L0	51	5.43 (4.86-6.26)	0.720 (0.487-1.036)	353 (185-478)	6.04 (0.00-38.1)	6.71 (3.56-9.79)	583 (260-856)	158 (61.9-383)	12.1 (5.92-43.8)	170 (72.0-348)	116 (52.4-293)	535 (202-1350)	303 (153-558)	81.1 (18.8-181)	18.8 (10.4-30.7)	46.7 (0.00-204)	6550 (4012-12652)	155 (70.6-414)	4.69 (1.46-11.0)
L1	26	5.95 (4.81-6.71)	0.104 (0.069-0.566)	39.7 (18.4-147)	0.00 (0.00-96.5)	4.08 (2.76-16.1)	708 (398-1200)	171 (56.2-425)	37.3 (9.90-75.1)	80.1 (11.5-199)	0.00 (0.00-33.9)	360 (236-1264)	391 (58.4-901)	94.4 (24.9-250)	16.6 (8.80-30.0)	24.3 (0.00-142)	5493 (1692-14662)	11.7 (7.1-27.9)	18.36 (3.78-29.7)
L2	35	4.92 (4.59-6.68)	0.071 (0.036-0.182)	26.9 (11.5-71.4)	54.8 (0.00-132)	4.60 (1.46-10.6)	695 (379-1093)	177 (76.6-299)	34.1 (13.1-65.1)	28.7 (7.57-59.7)	0.00 (0.00-21.3)	534 (295-1082)	280 (18.1-804)	83.1 (21.8-194)	20.8 (11.6-42.5)	0.00 (0.00-124)	4535 (568-11341)	20.8 (3.8-60.0)	14.91 (6.94-18.5)
L3	39	5.02 (4.55-6.87)	0.045 (0.026-0.125)	22.7 (9.99-46.7)	41.7 (0.00-227)	6.59 (1.46-11.4)	696 (426-1288)	145 (85.8-246)	29.1 (16.1-55.7)	13.4 (5.14-56.8)	0.00 (0.00-11.9)	443 (252-1426)	306 (35.6-921)	69.6 (33.8-121)	16.9 (9.12-50.9)	0.00 (0.00-198)	6100 (675-14800)	10.3 (0.5-60.0)	11.56 (6.87-15.7)
L4	37	5.32 (4.58-6.89)	0.056 (0.034-0.091)	20.1 (11.8-50.5)	0.00 (0.00-240)	12.16 (1.10-14.5)	765 (557-1239)	155 (106-266)	36.5 (22.5-65.0)	11.7 (3.15-77.8)	0.00 (0.00-13.1)	782 (257-1356)	326 (48.0-871)	80.0 (46.7-175)	23.9 (8.38-58.5)	1.70 (0.00-128)	4810 (1677-7811)	9.1 (0.5-28.7)	12.86 (8.40-18.4)
SW	53	6.84 (6.49-7.02)	0.014 (0.009-0.029)	14.5 (9.83-23.1)	0*	0.00 (0.00-0.00)	243 (192-266)	172 (141-206)	29.4 (25.6-44.7)	7.42 (4.68-10.5)	0.00 (0.00-0.00)	174 (137-202)	13.5 (8.28-59.1)	17.4 (13.4-28.9)	4.63 (3.62-5.97)	215 (140-255)	270 (112-1064)	38.6 (27.5-72.8)	14.52 (12.9-16.0)
2003																			
WO	37	4.32 (3.86-5.16)	0*	0*	0*	0*	44.9 (18.0-105)	8.23 (0.00-16.5)	4.35 (4.35-13.1)	10.2 (4.09-23.0)	121 (46.1-252)	189 (88.2-387)	70.7 (26.4-126)	12.5 (4.40-19.6)	5.68 (3.30-12.4)	0.00 (0.00-1.17)	ND	ND	0*
BP	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CTF	49	5.88 (4.50-6.56)	0.17 (0.06-0.51)	98.5 (50.2-179)	0.00 (0.00-43.8)	1.13 (0.32-6.11)	299 (168-719)	41.1 (24.7-166)	13.1 (8.70-27.0)	84.4 (40.9-278)	183 (72.7-377)	470 (203-888)	101 (44.0-276)	39.8 (19.5-133)	16.5 (9.17-59.2)	93.3 (0.00-199)	4445 (2485-9010)	118 (42.2-273)	1.07 (0.54-2.17)
FTF	49	6.36 (4.55-6.85)	0.28 (0.12-0.55)	157 (71.0-354)	0.00 (0.00-52.3)	2.59 (0.77-5.58)	444 (209-888)	74.0 (32.9-248)	17.4 (8.70-39.2)	148 (65.5-377)	216 (94.6-482)	550 (249-1266)	144 (52.7-348)	68.3 (35.2-227)	22.7 (12.0-77.4)	142 (0.00-288)	6240 (3360-14158)	145 (43.1-441)	1.38 (0.84-4.05)
L0	51	5.22 (4.35-6.48)	0.68 (0.40-1.19)	237 (174-785)	51.9 (0.00-121)	7.60 (4.32-16.9)	570 (399-1038)	189 (82.3-403)	13.1 (8.70-30.5)	212 (69.1-455)	185 (46.8-645)	658 (296-1301)	322 (203-730)	88.0 (26.8-354)	22.2 (10.7-60.5)	31.6 (0.00-208)	9200 (5014-17738)	227 (34.0-652)	4.20 (1.88-10.3)
L1	15	5.12 (4.48-6.87)	0.08 (0.04-0.39)	60.2 (41.5-135)	47.5 (0.00-381)	9.90 (1.73-20.1)	561 (438-815)	82.3 (36.2-326)	13.1 (10.4-36.5)	15.3 (2.56-44.0)	0.00 (0.00-2.76)	399 (223-1032)	285 (92.5-510)	26.5 (16.1-67.1)	18.5 (9.56-59.8)	17.2 (0.00-165)	5035 (1823-8531)	23.6 (16.2-30.0)	11.6 (2.48-20.2)
L2	16	5.41 (4.63-6.54)	0.07 (0.02-0.15)	44.2 (34.9-63.7)	57.2 (0.00-461)	7.71 (0.96-9.75)	523 (419-864)	98.7 (53.5-197)	21.8 (10.9-45.7)	5.11 (2.56-10.2)	0.00 (0.00-2.36)	668 (299-956)	201 (80.9-510)	32.6 (15.6-101)	17.1 (12.1-44.0)	22.1 (0.00-102)	3500 (1690-6600)	18.0 (15.0-29.0)	7.55 (3.16-16.0)
L3	22	4.98 (4.60-6.53)	0.04 (0.02-0.13)	39.4 (34.0-55.0)	140 (0.00-353)	6.63 (1.52-9.60)	517 (373-918)	123 (57.6-196)	19.6 (8.70-38.3)	3.84 (2.56-35.6)	0.00 (0.00-0.00)	387 (292-1092)	229 (52.7-598)	26.2 (6.68-77.2)	17.4 (6.56-40.9)	0.00 (0.00-102)	6505 (2149-9399)	19.0 (14.0-30.2)	8.76 (5.15-14.1)
L4	17	5.32 (4.57-6.56)	0.04 (0.01-0.07)	37.5 (31.6-57.2)	222 (0.00-399)	7.47 (0.33-10.6)	727 (402-882)	107 (79.0-179)	21.8 (13.1-39.2)	5.11 (2.56-10.2)	0.00 (0.00-3.63)	783 (275-1153)	236 (31.5-562)	35.3 (12.3-105)	30.3 (9.36-49.0)	0.00 (0.00-44.2)	2900 (770-7228)	22.3 (15.1-29.0)	10.9 (6.41-14.5)
SW	49	6.90 (6.60-7.15)	0.02 (0.00-0.03)	38.0 (30.2-44.4)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	264 (172-294)	165 (115-189)	30.5 (26.1-34.8)	7.67 (5.11-10.2)	0.00 (0.00-0.00)	172 (137-194)	17.6 (7.70-84.2)	17.5 (10.9-24.7)	4.84 (3.26-6.01)	217 (93.5-254)	380 (114-1730)	34.0 (27.9-48.7)	13.9 (12.2-16.6)

* denotes assumed data; ND means that parameter is note determined or that sample is not collected. Measured values for Al_i and Alkalinity are set to 0 in the statistical calculation when pH was above 5.5 and below 5.0, respectively.

Lei Gong Shan

LGS	N	pH	UV	Colour	Ali	Alo	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	NH_4^{+}	SO_4^{2-}	NO_3^{-}	Cl^{-}	tot-F	Alkalinity	Tot-N	Tot-P	H_4SiO_4
2001			**E254nm**	**mg Pt L^{-1}**	**µmol L^{-1}**	**µmol L^{-1}**	**µeq L^{-1}**	**µeq L^{-1}**	**µeq L^{-1}**	**µeq L^{-1}**	**µeq L^{-1}**	**µeq L^{-1}**	**µeq L^{-1}**	**µeq L^{-1}**	**µeq L^{-1}**	**µeq L^{-1}**	**µg L^{-1}**	**µg L^{-1}**	**mg L^{-1}**
WO	16	5.06 (4.72-7.43)	0*	0*	0*	0*	47.8 (8.21-420)	50.3 (4.20-81.7)	5.13 (2.96-8.72)	3.39 (1.93-6.87)	14.1 (5.68-66.1)	53.4 (27.3-115)	8.55 (4.49-16.1)	77.8 (3.61-156)	3.15 (0.00-4.37)	52.6 (0.00-308)	ND	ND	0*
BP	16	4.92 (4.62-7.35)	0*	0*	0*	0*	32.9 (10.0-438)	31.1 (4.52-74.2)	6.07 (2.63-9.46)	6.84 (1.94-9.40)	11.4 (1.39-53.4)	71.0 (30.9-157)	6.30 (3.05-13.5)	61.1 (2.67-101)	3.42 (0.00-4.24)	0.00 (0.00-343)	ND	ND	0*
CTF	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
FTF	28	6.65 (5.43-7.17)	0.239 (0.110-0.461)	0.03 (0.01-2.50)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	335 (63.5-566)	75.0 (31.9-148)	11.4 (4.62-17.1)	70.0 (36.9-230)	1.61 (0.00-36.9)	159 (48.3-288)	24.8 (3.30-210)	66.4 (5.70-183)	4.63 (1.37-7.32)	205 (53.3-452)	0 (0-5771)	0.0 (0.0-116)	0.00 (0.00-0.51)
L0	11	6.13 (5.18-6.90)	0.864 (0.500-1.420)	95.5 (0.14-182)	0.00 (0.00-9.87)	3.93 (0.79-6.34)	431 (173-531)	148 (55.5-222)	15.0 (4.57-29.4)	96.2 (62.8-190)	4.64 (0.00-29.5)	160 (61.1-268)	93.2 (14.1-150)	117 (41.5-210)	3.79 (1.11-5.21)	198 (30.0-338)	11930 (8531-14763)	214.9 (0.0-375)	1.79 (0.00-3.03)
L1	23	6.88 (4.95-7.48)	0.116 (0.036-0.294)	0.03 (0.00-17.9)	0.00 (0.00-0.48)	0.00 (0.00-0.40)	296 (102-877)	52.1 (35.0-103)	12.9 (7.54-21.5)	11.1 (2.97-40.8)	1.36 (0.00-24.4)	124 (79.8-439)	13.6 (5.10-296)	73.2 (9.75-139)	0.00 (0.00-4.19)	68.5 (0.00-308)	4225 (1182-6222)	34.9 (9.2-244)	4.42 (0.46-9.17)
L2	18	6.80 (5.09-7.25)	0.034 (0.019-0.086)	0.60 (0.00-5.00)	0.00 (0.00-1.04)	0.00 (0.00-0.04)	456 (85.0-1136)	50.9 (25.5-163)	11.0 (6.60-20.3)	15.2 (3.70-27.6)	1.25 (0.00-5.19)	134 (45.4-841)	14.6 (4.04-404)	73.4 (9.67-217)	0.00 (0.00-3.80)	130 (10.8-234)	3643 (1232-7481)	42.2 (10.0-177)	5.69 (0.62-9.12)
L3	23	6.14 (5.44-7.34)	0.017 (0.012-0.040)	1.20 (0.00-3.84)	0.00 (0.00-0.00)	0.00 (0.00-1.59)	197 (33.8-674)	55.3 (26.4-119)	13.4 (8.13-23.8)	9.69 (1.76-18.9)	0.00 (0.00-4.40)	70.6 (30.4-184)	7.39 (3.47-294)	77.3 (10.7-211)	0.00 (0.00-3.69)	63.6 (2.17-289)	2771 (899-7928)	39.7 (12.9-243)	2.70 (0.48-7.95)
L4	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SW	18	7.29 (6.71-7.48)	0.017 (0.012-0.037)	0.00 (0.00-5.32)	0*	0.00 (0.00-0.00)	183 (42.4-348)	41.6 (20.8-495)	81.9 (72.0-90.6)	5.11 (3.65-8.95)	0.00 (0.00-9.02)	35.4 (31.3-43.8)	7.84 (0.00-20.8)	52.3 (8.49-92.9)	0.00 (0.00-4.00)	189 (107-480)	1358 (539-1950)	28.1 (4.8-49.6)	16.54 (1.89-17.8)
2002																			
WO	41	5.11 (4.39-6.90)	0*	0*	0*	0*	48.4 (11.1-206)	9.30 (3.29-14.5)	5.70 (1.09-14.1)	4.73 (2.30-10.4)	26.2 (6.35-105)	47.6 (26.8-114)	10.9 (5.21-34.9)	6.66 (0.00-14.0)	0.89 (0.00-2.38)	9.14 (0.00-172)	ND	ND	0*
BP	42	5.27 (4.52-7.07)	0*	0*	0*	0*	61.5 (13.2-203)	9.54 (3.87-17.7)	5.31 (1.81-31.0)	4.46 (2.11-12.4)	21.5 (3.59-82.8)	47.8 (28.8-127)	11.1 (4.18-39.3)	5.71 (1.02-19.5)	1.16 (0.00-3.37)	7.58 (0.00-162)	ND	ND	ND
CTF	36	5.65 (4.83-6.39)	0.152 (0.053-0.252)	17.5 (3.82-44.4)	0.00 (0.00-130)	0.37 (0.09-0.85)	72.6 (37.0-157)	21.4 (12.4-33.2)	6.42 (3.50-11.7)	52.1 (24.8-98.2)	14.4 (0.00-24.8)	75.5 (44.9-122)	6.68 (0.00-11.5)	16.1 (6.87-31.2)	1.71 (0.63-3.76)	33.6 (0.00-109)	443 (161-845)	43.9 (25.9-127)	0.05 (0.00-0.16)
FTF	50	5.82 (4.82-6.45)	0.160 (0.070-0.338)	20.4 (11.6-50.33)	0.00 (0.00-2.80)	0.43 (0.00-1.58)	87.2 (44.0-207)	23.2 (14.3-34.0)	6.70 (3.65-21.3)	51.8 (19.2-95.3)	16.0 (1.68-56.3)	77.4 (46.9-157)	7.58 (0.00-12.5)	16.5 (6.81-66.3)	1.74 (0.63-4.00)	54.0 (0.00-169)	681 (64-2205)	61.4 (29.6-110)	0.09 (0.01-0.37)
L0	28	5.37 (4.29-6.10)	1.181 (0.685-1.556)	186 (107-232.08)	2.65 (0.00-9.07)	3.60 (0.96-6.66)	233 (170-359)	67.7 (48.1-115)	7.68 (2.09-22.3)	138 (44.9-477)	20.3 (0.65-76.0)	99.9 (55.6-310)	135 (54.8-297)	36.2 (12.7-127)	2.18 (1.09-4.08)	68.6 (0.00-187.)	3339 (1511-11550)	157 (65.3-356)	0.61 (0.12-1.23)
L1	47	5.30 (4.67-6.70)	0.133 (0.041-0.312)	9.05 (0.02-36.9)	0.00 (0.00-13.0)	1.85 (0.10-4.43)	145 (65.0-326)	43.5 (28.9-87.6)	11.4 (5.87-20.7)	13.3 (2.24-36.6)	2.25 (0.00-13.4)	103 (73.0-157)	47.2 (3.43-245)	12.9 (3.35-73.1)	1.37 (0.00-2.25)	16.9 (0.00-88.3)	1045 (89-3314)	18.0 (0.0-28.3)	2.03 (0.00-3.62)
L2	47	5.09 (4.63-6.77)	0.023 (0.009-0.082)	0.00 (0.00-9.80)	7.30 (0.00-13.8)	0.96 (0.00-2.34)	94.1 (44.7-505)	32.7 (21.6-58.8)	10.1 (5.49-17.7)	10.6 (2.63-24.8)	0.00 (0.00-5.68)	121 (64.8-267)	23.0 (0.00-195)	12.4 (2.66-40.3)	0.42 (0.00-1.63)	0.00 (0.00-101)	426 (0-3911)	14.9 (0.7-21.0)	2.51 (0.96-3.46)
L3	51	5.99 (5.26-6.74)	0.013 (0.002-0.025)	0.00 (0.00-2.60)	0.00 (0.00-3.09)	0.17 (0.00-0.76)	80.3 (37.0-333)	28.3 (21.6-55.9)	11.5 (5.39-20.5)	6.47 (2.13-13.9)	0.28 (0.00-7.43)	70.6 (35.4-108)	17.8 (0.00-182)	9.67 (2.23-28.2)	0.00 (0.00-1.26)	17.7 (4.69-95.9)	467 (31-3749)	16.6 (4.0-23.0)	2.50 (0.00-3.33)
L4	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SW	50	6.76 (6.32-7.24)	0.009 (0.004-0.017)	0.00 (0.00-4.79)	0*	0.00 (0.00-0.08)	78.6 (43.3-179)	21.3 (18.0-27.7)	77.6 (66.1-85.7)	5.09 (3.37-6.90)	0.00 (0.00-2.76)	35.9 (30.4-44.2)	20.1 (10.6-25.8)	9.42 (5.07-11.9)	0.00 (0.00-1.56)	103 (81.5-234)	355 (215-811)	31.2 (10.2-36.6)	7.80 (6.85-8.15)
2003																			
WO	32	4.73 (4.01-5.43)	0*	0*	0*	0*	19.5 (5.84-99.5)	4.11 (2.22-16.1)	2.61 (0.87-7.39)	4.22 (1.02-12.9)	30.7 (8.57-127)	56.5 (21.9-181)	17.9 (7.64-50.0)	2.82 (0.28-9.79)	0.11 (0.00-4.16)	0.00 (0.00-7.93)	ND	ND	0*
BP	35	4.73 (4.09-5.57)	0*	0*	0*	0*	29.4 (7.49-85.0)	4.94 (1.65-17.8)	4.00 (1.74-20.7)	3.58 (1.28-16.5)	28.6 (2.86-119)	60.5 (29.9-225)	18.6 (7.14-59.1)	4.96 (0.56-24.5)	0.11 (0.00-4.00)	0.00 (0.00-11.7)	ND	ND	ND
CTF	47	5.27 (4.53-6.06)	0.20 (0.08-0.38)	27.2 (4.38-53.6)	4.35 (0.00-15.2)	0.78 (0.30-2.25)	121 (33.4-328)	34.6 (9.05-86.4)	11.3 (4.78-27.6)	73.5 (27.6-170)	31.1 (10.7-81.7)	220 (29.3-534)	26.4 (5.71-88.5)	22.9 (5.36-75.5)	3.68 (0.53-8.84)	21.8 (0.00-54.6)	1460 (650-4032)	43.4 (26.3-82.9)	0.11 (0.00-0.26)
FTF	59	5.59 (4.46-6.22)	0.20 (0.09-0.33)	29.1 (10.3-51.1)	0.00 (0.00-8.95)	0.82 (0.17-1.83)	136 (43.6-284)	37.8 (11.5-68.9)	10.4 (4.26-28.7)	66.3 (22.4-142)	29.3 (7.85-80.5)	171 (36.6-402)	24.3 (5.71-94.4)	19.5 (5.25-62.2)	2.63 (0.00-6.95)	38.1 (0.00-100)	1450 (570-3896)	41.6 (27.9-108)	0.10 (0.00-0.37)
L0	28	5.46 (4.57-6.08)	1.23 (0.93-2.04)	209 (144-340)	8.52 (0.00-28.5)	4.56 (0.98-9.58)	288 (162-640)	80.5 (27.5-169)	7.83 (5.69-20.4)	164 (27.3-563)	39.6 (11.6-82.3)	122 (51.2-573)	131 (60.6-885)	27.8 (14.1-170)	1.97 (0.00-4.68)	64.4 (0.00-164)	4465 (2331-13826)	162 (52.8-600)	0.34 (0.12-1.14)
L1	51	4.93 (4.48-5.23)	0.07 (0.03-0.31)	5.66 (0.00-45.8)	13.0 (0.00-51.1)	2.87 (0.23-5.82)	102 (40.4-764)	45.3 (28.8-79.6)	8.26 (4.78-21.1)	6.91 (1.28-45.8)	0.00 (0.00-2.86)	92.4 (68.6-477)	46.1 (7.14-395)	12.1 (2.26-40.3)	0.53 (0.00-3.16)	0.00 (0.00-20.9)	1370 (529-5743)	15.6 (0.03-24.4)	2.86 (0.00-4.44)
L2	46	4.79 (4.62-4.89)	0.02 (0.01-0.05)	0.00 (0.00-4.72)	24.7 (0.00-40.9)	1.78 (0.39-4.32)	59.7 (25.0-225)	30.5 (16.8-60.9)	10.0 (4.63-30.5)	7.42 (0.51-15.1)	0.00 (0.00-1.04)	110 (61.9-192)	24. (0.00-171)	10.7 (0.45-25.8)	0.00 (0.00-3.16)	0.00 (0.00-21.0)	630 (165-3220)	12.6 (0.00-25.7)	1.96 (0.00-3.88)
L3	47	5.24 (4.90-6.14)	0.01 (0.00-0.03)	0.00 (0.00-4.35)	4.01 (0.00-19.3)	0.50 (0.11-1.46)	52.4 (22.6-295)	26.3 (19.1-69.1)	11.7 (4.57-30.8)	2.56 (1.02-18.6)	0.00 (0.00-1.00)	62.4 (31.8-109)	10.0 (0.00-273)	5.08 (0.03-17.8)	0.00 (0.00-0.63)	5.93 (0.00-22.2)	440 (118-7073)	13.4 (0.08-22.1)	2.75 (0.57-3.51)
L4	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SW	47	6.56 (6.42-6.67)	0.01 (0.00-0.02)	0.38 (0.00-4.35)	0*	0.04 (0.00-0.29)	45.4 (35.9-57.2)	20.6 (18.1-24.2)	80.0 (70.7-86.9)	4.09 (2.20-5.40)	0.00 (0.00-2.43)	35.6 (32.4-40.2)	24.3 (16.3-32.0)	5.64 (3.84-8.57)	0.00 (0.00-3.16)	81.7 (68.7-110)	530 (208-830)	36.1 (19.8-48.2)	7.71 (7.04-8.41)

* denotes assumed data; ND means that parameter is note determined or that sample is not collected. Measured values for Al_i and Alkalinity are set to 0 in the statistical calculation when pH was above 5.5 and below 5.0, respectively.

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LXH	N	pH	UV	Colour	Ali	Alo	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	NH_4^{+}	SO_4^{2-}	NO_3^{-}	Cl^{-}	tot-F	Alkalinity	Tot-N	Tot-P	H_4SiO_4
2002			E254nm	mg Pt L^{-1}	µmol L^{-1}	µmol L^{-1}	µeq L^{-1}	µeq L^{-1}	µeq L^{-1}	µeq L^{-1}	µeq L^{-1}	µeq L^{-1}	µeq L^{-1}	µeq L^{-1}	µeq L^{-1}	µeq L^{-1}	µg L^{-1}	µg L^{-1}	mg L^{-1}
WO	33	4.44 (3.93-5.16)	0*	0*	0*	0*	53.2 (28.0-118)	34.1 (10.8-48.3)	24.8 (8.46-69.6)	11.0 (5.35-32.5)	23.1 (1.21-100)	69.4 (24.3-174)	36.1 (12.0-65.6)	19.7 (6.37-58.3)	3.68 (1.88-13.7)	0.00 (0.00-0.00)	ND	ND	0*
BP	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CTF	16	5.27 (4.54-5.82)	0.160 (0.082-0.430)	51.4 (14.0-124)	0.70 (0.00-3.70)	2.93 (1.87-4.96)	40.8 (8.66-63.5)	22.7 (6.6-32.4)	9.92 (4.89-20.7)	219 (66.3-356)	10.1 (0.79-27.7)	95.7 (72.8-132)	29.5 (9.42-106)	61.2 (30.0-260)	4.34 (3.11-8.97)	16.3 (0.00-112)	617 (320-2357)	0.07 (0.06-0.10)	0.96 (0.20-5.05)
FTF	32	4.98 (4.46-5.40)	0.152 (0.087-0.476)	33.1 (6.25-163)	1.78 (0.06-4.43)	3.47 (2.05-6.18)	85.1 (35.3-157)	44.5 (16.0-73.5)	19.3 (10.4-29.2)	56.5 (24.4-109)	23.4 (4.62-55.4)	92.6 (60.2-156)	33.8 (13.1-108)	44.5 (19.1-89.6)	4.32 (3.06-8.94)	0.00 (0.00-33.9)	1762 (465-3855)	0.07 (0.03-0.15)	0.91 (0.29-2.31)
L0	40	5.28 (4.76-5.84)	0.539 (0.329-1.197)	122.25 (66.4-3)	1.00 (0.00-5.48)	10.8 (5.62-16.4)	128 (74.4-207)	69.4 (38.0-115)	20.8 (12.6-39.5)	96.5 (53.4-232)	49.8 (8.00-214)	105 (66.9-290)	92.9 (38.4-243)	52.1 (20.7-195)	5.13 (3.26-10.2)	23.5 (0.00-88.5)	4669 (1722-10193)	0.14 (0.05-0.24)	2.84 (1.04-6.02)
L1	30	4.53 (4.15-4.94)	0.045 (0.017-0.087)	0.13 (0.00-5.04)	32.2 (8.52-60.4)	4.35 (2.54-8.16)	55.3 (23.3-118)	39.3 (15.7-62.4)	37.3 (16.9-82.4)	38.8 (12.5-108)	3.41 (0.71-27.1)	63.2 (43.0-110)	60.1 (22.0-285)	36.8 (15.8-65.2)	5.24 (2.41-10.7)	0*	2657 (428-9022)	0.07 (0.04-0.11)	8.14 (4.70-10.20)
L2	34	4.51 (4.12-4.81)	0.025 (0.013-0.046)	0.00 (0.00-2.81)	27.5 (12.5-61.7)	3.66 (1.83-8.17)	53.9 (21.6-126)	41.7 (16.7-73.5)	27.9 (13.2-62.6)	39.4 (8.58-123)	1.21 (0.00-18.0)	73.4 (45.6-113)	95.9 (15.6-240)	29.2 (13.2-64.0)	5.84 (2.87-11.0)	0*	2466 (450-7100)	0.08 (0.05-0.12)	7.18 (4.28-9.44)
L3	36	4.77 (4.21-5.12)	0.016 (0.006-0.031)	0.00 (0.00-0.79)	19.3 (3.57-60.4)	2.24 (0.49-6.37)	52.8 (21.3-161)	38.0 (14.0-60.2)	29.5 (10.5-51.9)	22.5 (7.97-86.4)	1.00 (0.00-16.8)	83.3 (32.4-184)	41.5 (15.5-279)	18.6 (11.5-57.7)	6.55 (2.47-18.6)	0.00 (0.00-0.66)	1477 (476-6229)	0.08 (0.05-0.11)	6.40 (3.75-9.51)
L4	25	5.30 (4.69-5.91)	0.011 (0.001-0.025)	0.00 (0.00-0.79)	1.04 (0.00-15.4)	2.08 (0.83-6.12)	42.0 (17.5-83.1)	33.3 (10.4-46.5)	30.8 (11.8-64.3)	15.6 (8.94-85.1)	1.21 (0.00-12.5)	29.3 (5.61-45.2)	43.3 (22.1-141)	24.2 (14.8-56.2)	5.05 (1.55-11.0)	14.7 (0.00-38.4)	1222 (597-5573)	0.07 (0.05-0.13)	6.92 (5.62-10.4)
SW	48	6.67 (6.40-6.84)	0.024 (0.013-0.043)	0.79 (0.00-7.47)	0*	0.41 (0.21-0.46)	42.4 (4.13-88.9)	31.5 (4.07-40.0)	70.7 (29.0-125)	20.6 (7.58-30.3)	11.1 (0.00-29.1)	24.8 (15.3-39.3)	10.2 (2.52-15.5)	21.7 (11.3-39.3)	9.19 (6.90-10.7)	72.5 (40.1-110)	596 (208-927)	0.07 (0.03-0.09)	12.6 (10.5-14.7)
2003																			
WO		4.74 (4.29-4.98)	0*	0*	0*	0*	51.6 (15.6-127)	14.8 (4.28-34.5)	38.1 (6.48-82.4)	11.0 (2.22-21.4)	19.6 (1.14-50.4)	88.9 (40.4-182)	12.5 (2.93-53.6)	20.2 (5.30-52.0)	5.18 (2.70-9.71)	0.00 (0.00-0.00)	ND	ND	0*
BP	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CTF	44	5.86 (5.15-6.60)	0.19 (0.10-0.33)	63.5 (27.5-114)	0.00 (0.00-11.7)	2.71 (0.70-3.93)	49.4 (18.56-173)	23.0 (7.65-85.1)	15.2 (5.65-36.8)	175 (61.5-439)	9.82 (0.79-60.0)	143 (91.5-308)	17.1 (2.65-48.1)	54.6 (28.6-141)	6.66 (4.22-13.7)	27.0 (5.67-95.3)	1355 (504-4226)	0.08 (0.06-0.10)	0.75 (0.20-1.48)
FTF	43	5.31 (4.71-6.10)	0.14 (0.10-0.34)	43.3 (25.5-87.4)	2.39 (0.00-10.2)	3.71 (1.62-6.93)	56.9 (19.6-184)	27.2 (7.40-66.1)	13.9 (6.09-33.4)	84.9 (43.7-314)	19.5 (0.79-73.0)	145 (82.6-297)	14.2 (4.37-42.0)	44.0 (29.3-153)	6.74 (4.65-13.1)	27.8 (0.00-51.3)	1802 (552-5071)	0.07 (0.06-0.10)	1.04 (0.38-2.22)
L0	36	5.10 (4.76-5.66)	0.48 (0.32-0.76)	123 (64.6-206)	10.7 (0.00-21.2)	5.97 (1.91-10.1)	128 (53.4-355)	48.5 (19.3-135)	16.1 (5.44-35.0)	149 (66.5-325)	26.4 (0.79-128)	155 (96.7-334)	57.2 (2.82-167)	51.5 (27.5-118)	6.97 (3.97-10.8)	25.5 (0.00-40.9)	3094 (1349-7581)	0.11 (0.09-0.18)	1.49 (0.40-2.70)
L1	26	4.68 (4.54-5.09)	0.04 (0.02-0.06)	0.40 (0.40-2.80)	48.0 (6.05-116)	3.32 (1.39-13.8)	27.7 (12.0-76.9)	14.8 (6.58-38.3)	26.3 (9.57-49.8)	22.8 (13.6-45.9)	0.79 (0.79-27.2)	82.7 (47.4-109)	19.9 (6.82-66.2)	31.3 (12.1-48.2)	8.24 (3.63-10.8)	0*	825 (466-2219)	0.07 (0.06-0.09)	6.88 (4.44-8.41)
L2	32	4.67 (4.41-4.95)	0.02 (0.01-0.04)	0.40 (0.40-0.80)	60.0 (0.05-183)	3.91 (2.45-11.3)	37.4 (16.5-109)	21.8 (7.49-50.7)	21.1 (9.70-49.5)	29.3 (13.6-75.6)	0.79 (0.79-26.9)	83.9 (51.2-116)	26.3 (10.6-83.2)	24.5 (14.1-52.2)	6.61 (3.69-13.4)	0*	985 (607-3334)	0.07 (0.06-0.10)	7.34 (4.43-8.52)
L3	31	4.76 (4.40-5.37)	0.01 (0.00-0.04)	0.40 (0.40-0.40)	49.2 (0.00-180)	4.17 (2.12-19.1)	28.9 (9.48-102)	13.2 (6.58-51.0)	19.1 (4.35-47.4)	28.1 (6.65-93.1)	0.79 (0.79-50.8)	78.6 (43.7-106)	19.4 (6.35-125)	18.9 (6.49-45.1)	6.11 (2.84-13.6)	0.00 (0.00-40.9)	950 (660-3956)	0.07 (0.06-0.09)	5.18 (3.64-8.40)
L4	24	5.53 (5.05-6.08)	0.02 (0.00-0.03)	0.40 (0.40-0.80)	0.00 (0.00-60.2)	1.67 (1.05-2.29)	18.5 (8.48-32.6)	9.05 (3.29-19.7)	26.5 (9.13-36.7)	15.6 (8.90-50.9)	0.79 (0.79-10.3)	32.8 (24.3-53.3)	14.6 (7.56-31.1)	21.2 (14.6-34.3)	5.40 (3.46-10.4)	17.1 (0.00-74.6)	720 (323-1080)	0.07 (0.06-0.10)	6.21 (5.36-8.03)
SW	52	6.60 (6.47-6.82)	0.02 (0.01-0.04)	2.80 (0.40-4.80)	0*	0*	22.2 (3.64-52.3)	7.82 (1.73-12.3)	63.5 (31.19-83.3)	18.8 (12.7-26.1)	0.79 (0.79-12.8)	30.9 (21.9-50.5)	3.00 (1.07-5.35)	21.3 (15.3-29.3)	11.00 (7.71-14.1)	73.1 (58.8-103)	209 (71.8-356)	0.05 (0.04-0.07)	14.64 (13.2-15.6)

* denotes assumed data; ND means that parameter is note determined or that sample is not collected. Measured values for Al_i and Alkalinity are set to 0 in the statistical calculation when pH was above 5.5 and below 5.0, respectively.

Table B.3 Average soil physical and chemical properties. The abbreviations have the following denotation; N=number of samples, W_{dm}=desity,W_{H2O}=Water content, LOI=Loss on ignition, pH in specified extractants, CEC=Effective cation exchange capacity, BS=Base saturation, AlS=Aluminum saturation, C=Carbon, N=Nitrogen, C/N=C to N ratio, SO_4^{2-}=Adsorbed sulphate

Tie Shan Ping

Macro	N	W_{dm}	W_{H2O}	LOI	pH			pH	H^+	K^+	Na^+	Mn^{2+}	Fe^{n+}	Ca^{2+}	Mg^{2+}	Al^{n+}	CEC	BS	AlS	C	N	C/N	SO_4^{2-}
plot		%			H_2O	KCl	$CaCl_2$	$BaCl_2$	meq/100g									%					mmol/kg
											A horizon												
1	5	96.7	3.45	27.3	3.56	3.00	3.09	2.87	3.09	0.38	0.16	0.14	0.71	2.79	0.56	4.94	12.8	30.5	39.2	12.2	0.57	21.0	0.58
2	5	96.8	3.34	24.9	3.86	3.45	3.20	3.22	1.84	0.48	0.12	0.53	0.44	3.35	0.32	6.65	13.7	30.6	49.0	19.7	0.87	22.7	0.59
3	5	95.7	4.48	29.7	3.79	3.81	3.64	3.63	0.90	0.42	0.09	0.24	0.46	1.56	0.34	8.69	12.7	18.9	67.9	14.1	0.64	21.8	0.70
4	5	96.4	3.78	25.9	3.31	3.01	2.97	3.05	3.47	0.44	0.07	0.10	0.94	2.79	0.37	8.07	16.2	21.9	52.0	13.3	0.61	21.6	0.56
5	5	97.4	2.71	20.6	3.84	3.73	3.59	3.43	2.18	0.24	0.08	0.19	0.48	1.14	0.33	4.77	9.42	21.0	51.9	8.57	0.44	19.5	0.79
6	5	97.7	2.32	15.4	3.93	3.24	3.11	3.14	2.25	0.26	0.07	0.16	0.52	1.22	0.29	3.89	8.66	20.9	50.6	9.83	0.45	21.6	0.71
7	5	97.0	3.14	28.0	3.54	3.00	3.06	2.86	4.45	0.44	0.14	0.22	0.86	2.53	0.65	5.34	14.6	25.4	37.9	19.7	0.86	22.2	0.46
8	5	97.0	3.13	21.5	3.23	3.11	3.08	3.04	2.97	0.41	0.09	0.07	0.80	2.93	0.32	5.01	12.6	31.1	39.9	14.6	0.57	25.3	0.49
9	5	97.5	2.59	16.8	3.81	3.65	4.07	3.16	2.17	0.32	0.09	0.17	0.48	2.31	0.41	3.70	9.65	33.1	39.7	8.27	0.38	21.5	0.51
10	5	97.5	2.60	17.5	3.40	3.02	3.22	2.87	2.51	0.32	0.08	0.18	0.59	2.81	0.42	4.32	11.2	32.0	39.3	8.52	0.42	20.4	0.61
											B horizon												
1	5	99.0	0.97	4.36	3.67	3.16	3.39	3.33	0.42	0.06	0.04	0.05	0.10	0.18	0.09	2.46	3.4	10.7	72.3	1.07	0.08	13.5	2.21
2	1	99.4	0.63	3.19	3.56	3.34	3.20	3.27	0.45	0.07	0.03	0.06	0.06	0.28	0.05	1.82	2.81	14.9	64.8	1.13	0.07	16.1	1.17
3	1	99.1	0.89	4.81	3.51	2.99	3.24	3.19	0.55	0.09	0.02	0.02	0.19	0.47	0.08	2.92	4.36	15.4	67.1	2.64	0.10	26.4	0.89
4	5	98.7	1.30	4.74	3.50	3.05	3.37	3.28	0.48	0.10	0.02	0.02	0.18	0.21	0.07	3.01	4.07	9.5	74.1	1.60	0.09	18.8	1.53
5	5	99.3	0.74	2.91	3.59	3.29	3.31	3.36	0.40	0.06	0.02	0.09	0.05	0.15	0.05	1.76	2.58	10.7	68.2	0.95	0.07	13.4	1.12
6	5	99.0	1.01	3.44	3.69	3.31	3.58	3.31	0.47	0.10	0.02	0.15	0.06	0.27	0.07	2.24	3.38	13.8	66.3	0.94	0.08	12.4	1.65
7	1	99.3	0.69	3.13	4.38	3.06	3.15	3.29	0.44	0.10	0.02	0.06	0.08	0.24	0.07	2.28	3.28	13.1	69.4	0.95	0.07	13.6	1.83
8	1	99.2	0.77	3.79	3.61	2.97	3.20	3.19	0.55	0.09	0.01	0.01	0.16	0.33	0.07	2.52	3.74	13.5	66.8	1.07	0.06	17.8	0.97
9	1	99.3	0.66	3.07	3.43	3.08	2.75	3.37	0.36	0.06	0.02	0.02	0.06	0.22	0.05	1.82	2.62	13.3	69.5	0.72	0.06	12.0	0.73
10	1	99.1	0.91	3.69	3.59	3.10	3.34	3.33	0.40	0.06	0.03	0.02	0.09	0.28	0.06	2.79	3.73	11.7	74.6	0.79	0.06	13.2	3.54
											C horizon												
1	5	99.0	0.96	4.04	3.80	3.39	3.58	3.50	0.28	0.05	0.04	0.06	0.03	0.10	0.06	2.35	2.96	8.2	79.5	0.55	0.05	10.8	4.49
4	5	98.8	1.18	3.86	3.82	3.21	3.34	3.43	0.32	0.07	0.01	0.02	0.06	0.17	0.05	2.57	3.27	9.0	78.5	0.96	0.07	14.0	3.16
5	5	99.2	0.78	2.38	3.77	3.39	3.53	3.55	0.25	0.05	0.02	0.14	0.00	0.12	0.03	1.54	2.16	10.6	71.3	0.57	0.05	12.8	2.48
6	5	99.1	0.92	2.98	3.81	3.36	3.86	3.59	0.23	0.06	0.02	0.18	0.00	0.16	0.04	1.83	2.53	11.5	72.1	0.50	0.05	10.9	4.02

Liu Chon Guang

Macro	N	W_{dm}	W_{H2O}	LOI	pH			pH	H^+	K^+	Na^+	Mn^{2+}	Fe^{n+}	Ca^{2+}	Mg^{2+}	Al^{n+}	CEC	BS	AlS	C	N	C/N	SO_4^{2-}
plot		%			H_2O	KCl	$CaCl_2$	$BaCl_2$	meq/100g									%					mmol/kg
												A horizon											
1	5	96.4	3.76	22.9	3.51	3.08	3.09	2.99	2.59	0.30	0.05	0.05	1.09	3.68	0.58	9.49	17.8	26.2	53.2	10.5	0.55	19.2	1.93
2	5	93.8	6.62	48.6	3.48	2.89	2.95	2.71	5.53	0.65	0.08	0.12	1.49	12.4	1.39	10.5	32.1	42.6	34.6	26.5	1.27	20.5	1.12
3	5	93.9	6.47	46.5	3.56	2.95	2.95	2.76	4.78	0.52	0.08	0.14	1.69	6.37	1.08	12.6	27.3	28.6	46.6	27.3	1.06	28.2	1.29
4	5	94.5	5.77	42.2	3.94	3.55	3.59	3.32	1.81	0.84	0.10	2.32	0.55	13.1	1.70	8.19	28.6	54.7	28.9	22.8	1.35	16.9	0.72
5	5	93.3	7.14	55.6	3.50	2.91	2.95	2.73	5.15	0.71	0.09	0.25	1.64	15.3	1.51	9.01	33.6	51.3	27.4	31.9	1.46	21.8	0.94
6	5	95.7	4.48	30.3	3.81	3.47	3.42	3.22	1.38	0.49	0.05	0.68	0.58	4.49	0.75	9.12	17.5	27.1	58.9	16.8	1.00	16.9	0.93
7	5	94.6	5.70	37.7	3.85	3.30	3.32	3.12	2.11	0.54	0.09	0.21	1.16	8.79	1.03	10.7	24.6	37.2	47.7	19.9	1.01	19.5	1.61
8	5	95.8	4.42	28.5	3.65	3.05	3.13	2.92	3.38	0.34	0.07	0.04	1.22	5.28	0.69	8.87	19.9	31.4	45.3	16.0	0.75	21.5	0.67
9	5	95.1	5.16	34.5	3.73	3.20	3.23	3.07	2.86	0.42	0.06	0.10	1.17	6.84	0.82	10.9	23.2	33.3	48.3	18.9	0.97	19.6	1.58
10	5	97.3	2.73	17.7	3.56	3.02	3.09	2.83	1.81	0.19	0.04	0.02	0.68	2.58	0.43	4.96	10.7	28.9	47.6	9.85	0.47	21.3	0.43
												B1 horizon											
1	5	97.6	2.46	12.0	3.70	3.30	3.33	3.08	0.94	0.17	0.03	0.05	0.39	1.16	0.32	6.56	9.62	17.5	68.7	4.50	0.24	18.9	1.27
2	5	96.4	3.76	12.2	3.60	3.15	3.18	3.04	0.91	0.30	0.04	0.03	0.61	2.29	0.46	10.2	14.8	20.0	69.7	4.31	0.21	19.9	0.98
3	5	96.8	3.30	8.05	3.73	3.20	3.27	3.13	0.68	0.20	0.03	0.02	0.44	1.19	0.29	7.21	10.1	17.0	71.7	2.26	0.10	21.6	1.36
4	5	98.1	1.93	8.52	4.20	3.60	3.66	3.46	0.31	0.19	0.03	0.48	0.03	1.39	0.39	4.68	7.49	26.8	61.8	2.23	0.15	14.6	1.21
5	5	97.6	2.41	6.44	3.74	3.04	3.14	2.94	1.14	0.22	0.02	0.04	0.27	1.28	0.40	6.55	9.92	19.2	66.5	0.77	0.06	14.4	0.82
6	5	97.4	2.70	14.4	3.76	3.46	3.42	3.29	0.49	0.18	0.03	0.22	0.21	0.96	0.30	5.13	7.51	19.7	68.1	6.38	0.37	17.0	1.22
7	5	97.7	2.38	9.90	3.82	3.35	3.41	3.25	0.49	0.18	0.03	0.01	0.41	0.92	0.23	6.73	8.99	15.0	74.9	3.13	0.22	15.4	1.46
8	5	98.4	1.61	8.14	3.85	3.46	3.52	3.35	0.42	0.09	0.03	0.00	0.25	0.73	0.16	4.07	5.76	17.6	70.8	3.65	0.19	19.0	1.69
9	5	97.8	2.20	9.45	3.91	3.53	3.57	3.34	0.43	0.12	0.02	0.01	0.26	0.55	0.19	5.21	6.78	12.8	77.1	3.58	0.17	20.7	2.09
10	5	98.3	1.70	7.74	3.88	3.55	3.56	3.32	0.54	0.10	0.02	0.01	0.28	0.53	0.15	3.84	5.46	14.5	71.3	2.07	0.12	17.4	3.14
												B2 horizon											
1	5	98.0	2.09	6.51	3.89	3.54	3.58	3.46	0.31	0.12	0.03	0.01	0.18	0.68	0.16	5.53	7.00	13.8	79.1	1.34	0.09	14.0	2.82
6	5	98.0	2.02	7.03	3.99	3.53	3.53	3.39	0.37	0.16	0.02	0.04	0.11	0.64	0.19	5.59	7.13	14.5	78.1	1.45	0.10	14.1	1.39
7	5	98.4	1.64	6.41	4.00	3.58	3.64	3.49	0.30	0.11	0.02	0.00	0.16	0.50	0.13	4.45	5.66	13.4	78.2	1.34	0.08	18.2	3.19
10	5	98.2	1.80	7.15	4.10	4.04	4.00	3.73	0.17	0.07	0.02	0.00	0.08	0.27	0.09	2.52	3.22	13.6	78.6	2.08	0.11	19.5	4.62

Lei Gong Shan

Macro plot	N	W_{dm}	W_{H2O}	LOI	pH H_2O	pH KCl	pH $CaCl_2$	pH $BaCl_2$	H^+	K^+	Na^+	Mn^{2+}	Fe^{n+}	Ca^{2+}	Mg^{2+}	Al^{n+}	CEC	BS	AlS	C	N	C/N	SO_4^{2-}
		%	%	%					meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%	%	%	%		mmol/kg
A horizon																							
1	5	95.6	4.56	20.7	3.74	3.31	3.51	3.28	1.41	0.46	0.02	0.62	0.20	4.52	0.82	5.79	13.8	40.1	43.3	11.0	0.65	16.8	0.60
2	5	94.2	6.20	26.0	4.40	3.77	3.69	3.58	0.81	0.52	0.08	0.62	0.06	15.2	1.30	3.76	22.3	74.6	18.5	15.4	0.98	15.7	0.59
3	5	96.0	4.17	26.2	4.01	3.70	3.40	3.32	1.31	0.32	0.11	0.32	0.27	3.79	1.24	6.65	14.0	38.3	48.2	14.2	0.85	16.8	0.60
4	5	96.8	3.28	16.3	5.81	5.28	5.03	5.37	0.01	0.54	0.11	0.34	0.00	16.9	1.36	0.03	19.3	98.0	0.17	8.06	0.58	14.0	0.17
5	5	95.5	4.75	22.3	3.71	3.43	3.32	3.31	1.37	0.41	0.05	0.49	0.24	5.26	1.01	5.74	14.6	44.5	40.8	13.5	0.79	17.2	0.83
6	5	95.8	4.38	22.8	3.88	3.32	3.37	3.26	1.56	0.34	0.05	0.44	0.34	2.76	0.82	6.13	12.4	31.8	49.5	10.3	0.68	15.1	0.76
7	5	95.8	4.34	22.9	3.73	3.36	3.31	3.30	1.35	0.41	0.07	0.51	0.20	3.40	0.77	6.05	12.8	35.2	48.5	10.6	0.68	15.5	0.75
8	5	96.1	4.08	21.4	4.11	3.48	3.61	3.36	1.07	0.42	0.05	0.72	0.09	3.42	0.82	5.21	11.8	40.9	43.5	10.5	0.71	14.9	0.63
9	5	94.8	5.46	24.2	4.28	3.69	3.70	3.51	0.86	0.47	0.07	0.74	0.03	12.4	1.48	4.28	20.3	66.4	25.0	13.2	0.83	15.8	0.50
10	5	95.4	4.85	23.9	4.11	3.57	3.64	3.41	1.08	0.48	0.07	0.69	0.07	6.24	1.44	4.64	14.7	54.9	32.4	10.9	0.73	14.9	0.58
B1 horizon																							
1	5	97.3	2.74	12.8	3.91	3.60	3.70	3.63	0.21	0.15	0.02	0.09	0.04	0.65	0.21	2.81	4.2	24.5	67.5	4.8	0.36	12.9	1.60
2	5	94.6	5.72	19.8	4.07	3.72	3.69	3.84	0.35	0.23	0.05	0.12	0.04	2.72	0.47	3.71	7.69	39.7	53.5	9.8	0.64	15.3	1.40
3	1	96.4	3.76	16.8	4.22	3.57	3.61	3.55	0.25	0.08	0.05	0.05	0.09	0.48	0.31	3.71	5.03	18.4	73.8	6.49	0.43	15.1	1.61
4	5	97.9	2.16	10.0	5.39	4.53	5.09	4.14	0.07	0.13	0.10	0.14	0.00	6.92	0.99	0.21	8.55	94.8	2.6	4.36	0.38	11.1	0.36
5	1	97.2	2.83	14.3	4.33	3.83	3.88	3.66	0.19	0.1	0.03	0.06	0.03	0.71	0.25	3.09	4.46	24.4	69.3	10.1	0.69	14.7	1.91
6	1	97.4	2.66	13.1	4.31	3.70	3.77	3.58	0.23	0.11	0.05	0.10	0.04	0.68	0.21	2.36	3.77	27.7	62.6	5.82	0.44	13.2	2.39
7	1	97.1	2.98	14.0	4.30	3.65	3.73	3.57	0.24	0.14	0.05	0.09	0.05	0.54	0.25	2.61	3.96	24.5	65.9	5.67	0.43	13.2	1.77
8	5	97.6	2.42	12.3	4.45	3.82	4.16	3.70	0.18	0.12	0.03	0.10	0.01	0.78	0.26	2.04	3.54	34.0	57.7	4.01	0.35	11.3	1.98
9	1	96.3	3.85	17.2	4.9	3.81	4.04	3.76	0.15	0.18	0.03	0.09	0.02	1.52	0.41	2.43	4.83	44.4	50.3	5.34	0.39	13.7	1.14
10	1	96.7	3.38	13.6	4.49	3.75	3.81	3.61	0.21	0.14	0.05	0.07	0.03	0.82	0.31	2.41	4.03	32.7	59.7	4.19	0.37	11.3	1.14
B2 horizon																							
1	5	97.8	2.23	7.91	4.17	3.88	3.92	3.89	0.11	0.08	0.01	0.03	0.01	0.27	0.09	1.57	2.18	20.7	72.1	2.29	0.23	9.93	3.32
2	5	95.5	4.74	13.8	4.14	3.94	3.94	3.97	0.10	0.08	0.03	0.06	0.01	0.44	0.14	1.65	2.52	28.6	64.3	5.26	0.40	13.1	4.10
4	5	97.7	2.33	10.2	5.30	4.32	4.50	4.14	0.07	0.11	0.10	0.13	0.00	6.99	0.48	0.34	8.21	89.1	7.62	3.60	0.29	11.2	0.27
8	5	98.1	1.92	9.64	4.43	3.98	3.97	3.89	0.11	0.08	0.02	0.05	0.00	0.41	0.15	1.25	2.08	31.6	60.0	2.09	0.22	9.30	3.62

Caj Jia Tang

Macro plot	N	W_{dm}	W_{H2O}	LOI	pH H_2O	pH KCl	pH $CaCl_2$	pH $BaCl_2$	H^+	K^+	Na^+	Mn^{2+}	Fe^{n+}	Ca^{2+}	Mg^{2+}	Al^{n+}	CEC	BS	AlS	C	N	C/N	SO_4^{2-}
		%	%	%					meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%	%	%	%		mmol/kg
A horizon																							
1	5	97.6	2.42	10.7	3.98	3.65	4.60	3.62	0.37	0.32	0.27	1.04	0.01	4.00	0.73	1.29	8.03	64.3	17.6	6.73	0.39	17.1	0.41
2	5	97.0	3.13	12.6	4.83	3.85	3.77	3.39	0.38	0.41	0.25	2.21	0.01	4.14	0.75	1.63	9.78	56.5	17.0	6.36	0.39	16.3	0.47
3	5	96.9	3.23	15.0	4.12	3.83	3.86	3.01	0.91	0.47	0.25	1.76	0.07	5.54	1.18	3.19	13.4	54.1	25.6	10.0	0.48	21.1	0.45
4	5	97.5	2.55	13.5	3.99	4.02	3.65	2.87	1.26	0.45	0.26	0.19	0.17	3.08	0.64	4.40	10.4	41.3	43.1	6.65	0.38	17.7	0.58
5	5	97.4	2.66	14.2	3.92	3.72	4.46	2.77	1.55	0.39	0.25	0.38	0.20	2.12	0.59	4.93	10.4	31.9	47.6	6.60	0.30	22.0	0.58
6	5	95.9	4.28	18.0	3.78	3.78	3.95	3.20	0.74	0.59	0.36	3.76	0.05	3.38	0.94	6.34	16.1	34.1	36.3	10.1	0.59	17.5	0.58
7	5	94.9	5.38	23.0	4.20	3.66	3.56	3.03	2.69	1.04	0.73	0.63	0.29	2.70	0.77	10.8	19.7	26.4	55.4	11.8	0.67	17.8	0.85
8	5	96.6	3.49	18.1	4.19	3.11	4.05	2.91	1.98	0.79	0.44	0.63	0.26	4.92	1.11	8.01	18.1	38.9	44.5	10.1	0.56	18.0	0.58
9	5	96.2	3.94	18.4	3.80	3.51	4.04	3.08	1.62	0.63	0.48	0.86	0.14	3.61	0.75	6.36	14.5	36.8	46.2	9.43	0.48	19.7	0.74
10	5	96.6	3.48	15.6	4.08	3.66	3.59	3.22	0.75	0.51	0.27	0.93	0.06	1.82	0.45	5.97	10.8	28.0	56.0	8.09	0.44	18.4	0.82
B1 horizon																							
1	1	98.6	1.43	7.97	4.27	3.68	3.65	3.16	0.6	0.26	0.28	0.59	0.02	2.06	0.43	1.99	6.23	48.7	31.9	2.27	0.16	14.2	0.55
2	5	97.6	2.43	10.7	4.51	4.46	4.27	3.32	0.46	0.30	0.25	1.76	0.01	2.94	0.53	1.78	8.03	50.1	22.6	4.7	0.31	15.2	0.81
3	1	96.8	3.28	8.59	3.87	3.45	3.2	3.07	0.74	0.22	0.28	0.72	0.04	1.94	0.5	4.16	8.59	34.1	48.4	4.15	0.29	14.3	0.35
4	5	98.5	1.53	8.9	3.64	3.47	3.20	3.34	0.62	0.21	0.26	0.04	0.09	0.53	0.18	3.75	5.69	21.4	65.9	2.82	0.18	15.7	0.45
5	1	97.0	3.12	7.38	3.36	3.5	4.83	3.02	0.75	0.26	0.24	0.13	0.05	0.57	0.2	3.42	5.62	22.6	60.8	2.72	0.13	20.9	0.47
6	1	96.7	3.4	9.33	4.42	4.18	4.23	3.1	0.69	0.25	0.27	1.39	0.02	0.82	0.32	3.68	7.43	22.2	49.5	3.27	0.20	16.4	0.66
7	5	97.1	2.94	13.6	4.22	3.63	3.46	3.01	0.87	0.39	0.26	0.26	0.12	0.62	0.29	6.89	9.71	16.1	71.1	6.62	0.35	18.7	1.24
8	1	98.1	1.98	8.83	3.35	3.24	3.16	3.05	0.77	0.14	0.24	0.06	0.09	0.42	0.13	3.49	5.34	17.4	65.3	3.92	0.21	18.8	0.61
9	5	98.1	1.98	9.73	3.74	3.41	3.35	3.10	0.71	0.21	0.25	0.20	0.08	0.66	0.22	4.67	6.99	19.2	66.5	3.70	0.22	16.8	0.70
10	1	98.0	1.99	10.1	3.50	3.46	3.34	3.08	0.71	0.21	0.26	0.29	0.03	0.35	0.16	3.86	5.88	16.8	65.7	3.16	0.18	17.6	1.35
B2 horizon																							
2	5	98.1	1.90	5.85	4.71	4.19	3.97	3.54	0.28	0.15	0.22	0.49	0.00	1.21	0.22	1.74	4.31	42.5	39.7	1.71	0.15	11.5	1.09
4	5	98.7	1.28	5.47	3.99	3.73	3.46	3.39	0.38	0.12	0.21	0.02	0.02	0.18	0.07	3.25	4.26	14.0	75.8	1.54	0.14	10.8	0.82
7	5	98.0	2.06	7.62	3.90	3.77	3.53	3.69	0.22	0.18	0.22	0.11	0.01	0.17	0.09	3.41	4.41	16.3	75.8	2.02	0.13	15.5	2.62
9	5	98.3	1.73	5.79	4.09	4.33	3.66	3.35	0.41	0.15	0.25	0.08	0.02	0.22	0.09	3.33	4.55	15.9	73.1	1.72	0.13	13.1	1.84

Li Xi He

Macro	N	W_{dm}	W_{H2O}	LOI	pH			pH	H^+	K^+	Na^+	Mn^{2+}	Fe^{n+}	Ca^{2+}	Mg^{2+}	Al^{n+}	CEC	BS	AlS	C	N	C/N	SO_4^{2-}
Plot		%			H_2O	KCl	$CaCl_2$	$BaCl_2$	meq/100g									%					mmol/kg
											A horizon												
1	5	98.6	1.45	10.0	3.90	3.59	3.38	3.46	0.30	0.15	0.03	0.17	0.02	0.28	0.10	2.02	3.09	18.4	65.6	3.74	0.22	17.5	0.40
2	5	99.0	1.02	7.22	4.06	3.71	3.54	3.56	0.24	0.13	0.02	0.05	0.03	0.09	0.08	1.52	2.17	15.2	69.9	1.64	0.09	17.3	0.57
3	5	98.3	1.70	10.6	3.97	3.75	3.64	3.60	0.24	0.14	0.02	0.04	0.05	0.06	0.09	2.14	2.79	11.4	76.8	3.41	0.16	20.9	0.64
4	5	98.6	1.40	7.40	4.01	3.72	3.81	3.46	0.31	0.14	0.02	0.07	0.05	0.16	0.09	1.53	2.38	17.8	63.9	1.95	0.11	18.0	0.29
5	5	97.7	2.36	9.41	4.27	3.64	3.47	3.61	0.23	0.15	0.03	0.14	0.01	0.28	0.11	1.81	2.76	20.7	65.6	3.00	0.15	19.6	0.46
6	5	98.4	1.59	9.86	4.16	3.64	3.67	3.64	0.20	0.15	0.03	0.11	0.01	0.18	0.11	1.66	2.45	19.0	67.5	3.83	0.16	22.8	0.62
7	5	98.3	1.69	12.6	4.07	3.78	3.64	3.66	0.19	0.15	0.02	0.06	0.02	0.13	0.09	1.43	2.10	18.7	68.3	2.96	0.13	22.0	1.39
8	5	97.7	2.35	15.0	4.13	3.79	3.53	3.57	0.23	0.12	0.03	0.03	0.03	0.11	0.09	1.45	2.09	16.8	69.1	4.92	0.19	24.9	1.14
9	5	99.0	1.06	6.22	4.05	3.66	3.45	3.59	0.22	0.11	0.02	0.02	0.03	0.11	0.07	1.10	1.69	19.5	63.4	1.80	0.10	18.0	0.32
10	5	98.3	1.68	11.4	4.15	3.77	3.45	3.61	0.21	0.17	0.03	0.12	0.02	0.14	0.10	2.21	3.00	14.5	73.7	3.66	0.18	20.9	0.64
											AB horizon												
1	1	98.6	1.38	7.64	4.12	3.78	3.47	3.59	0.22	0.11	0.04	0.06	0.01	0.13	0.07	1.64	2.29	15.2	71.7	2.14	0.15	14.3	0.55
2	5	99.1	0.86	6.38	4.09	3.76	3.62	3.65	0.20	0.11	0.02	0.03	0.01	0.07	0.06	1.49	1.98	12.7	75.2	1.44	0.08	18.1	0.82
3	1	97.9	2.11	8.77	4.11	3.57	3.48	3.57	0.23	0.08	0.01	0.01	0.03	0.04	0.06	1.93	2.40	8.1	80.6	1.54	0.09	17.1	0.99
4	1	99.0	1.03	6.04	4.14	3.57	3.46	3.64	0.19	0.11	0.03	0.04	0.02	0.09	0.07	1.18	1.74	17.1	68.0	0.94	0.06	15.7	0.26
5	1	98.0	2.05	7.16	4.03	3.68	3.57	3.55	0.24	0.09	0.01	0.11	0.01	0.12	0.08	1.87	2.53	12.2	73.8	2.46	0.12	20.5	0.59
6	1	98.2	1.85	8.99	4.24	3.84	3.46	3.71	0.17	0.09	0.01	0.04	0.01	0.06	0.06	1.55	1.99	11.3	77.7	1.69	0.09	18.8	1.14
7	5	98.5	1.52	10.8	3.98	3.87	3.71	3.77	0.15	0.08	0.02	0.01	0.02	0.05	0.05	1.54	1.91	10.3	80.2	2.03	0.11	18.7	2.12
8	5	98.2	1.85	12.1	4.25	3.86	3.79	3.74	0.16	0.06	0.02	0.01	0.02	0.08	0.05	1.74	2.13	10.3	80.9	2.13	0.10	22.6	1.74
9	5	99.2	0.81	4.22	4.19	3.94	3.82	3.78	0.14	0.07	0.01	0.00	0.01	0.03	0.03	0.93	1.23	11.9	74.9	1.12	0.07	15.5	0.39
10	1	98.7	1.29	9.45	4.33	3.88	3.69	3.76	0.15	0.13	0.03	0.02	0.02	0.05	0.07	1.81	2.29	12.1	79.3	2.74	0.12	22.8	1.22
											B horizon												
2	5	99.2	0.84	6.03	4.17	3.71	3.53	3.72	0.16	0.11	0.01	0.02	0.01	0.06	0.04	1.49	1.91	11.7	78.0	0.84	0.05	12.8	1.41
7	5	98.8	1.26	9.93	3.92	3.77	3.65	3.74	0.16	0.06	0.02	0.01	0.02	0.05	0.04	1.53	1.89	8.9	80.7	1.34	0.07	19.3	3.77
8	5	98.6	1.37	10.0	3.95	3.64	3.46	3.80	0.14	0.05	0.02	0.00	0.01	0.05	0.04	1.98	2.29	7.1	85.6	1.16	0.06	18.1	2.46
9	5	99.3	0.68	3.61	4.28	3.90	3.73	3.85	0.12	0.06	0.03	0.00	0.01	0.04	0.03	1.25	1.53	9.7	81.2	0.51	0.05	11.7	0.77

Appendix C. Ground vegetation data

Table C-1. Year of establishment and year of performed/planned reanalysis of ground vegetation in each of the 5 catchments.

Catchment	Year of establishment	First reanalyses	Second reanalyses	Third reanalyses	Etc.
LCG	2000	2002	2005	2010	Etc.
TSP	2000	2002	2005	2010	Etc.
LGS	2001	2003	2006	2011	Etc.
CJT	2001	2003	2006	2011	Etc.
LXH	2002	2004	2007	2012	Etc.

Table C-2. The c ratio (c=a/b, where a is total number of species recorded in the five 1 m2 plots in each 10x10 m^2 macro plot and b is the total number of species recorded in each of the 30x30 m^2 plots (including a)) in four catchments (LCG, TSP, LGS, CJT) in 2 years.

Catchment	Results
LCG	The c ratio (=a/b) varied between 0.19 and 0.55 for the data set sampled in LCG in 2000 (Appendix Figure. C-1). The corresponding species numbers and c ratios recorded in LCG in 2002 varied between 0.33 and 0.54 (Appendix Figure. C-2).
TSP	The c ratio (=a/b) varied between 0.38 and 0.63 for the data set sampled in TSP in 2000 (Appendix Figure. C-3). The corresponding species numbers and c ratios recorded in TSP in 2002 varied between 0.39 and 0.66 (Appendix Figure. C-4).
LGS	The c ratio (=a/b) varied between 0.25 and 0.34 for the data set sampled in LGS in 2001 (Appendix Figure. C-5). The corresponding species numbers and c ratios recorded in LGS in 2003 varied between 0.36 and 0.46 (Appendix Figure. C-6).
CJT	The c ratio (=a/b) varied between 0.29 and 0.51 for the data set sampled in CJT in 2001 (Appendix Figure. C-7). The corresponding species numbers and c ratios recorded in CJT in 2003 varied between 0.31and 0.53 (Appendix Figure. C-8).

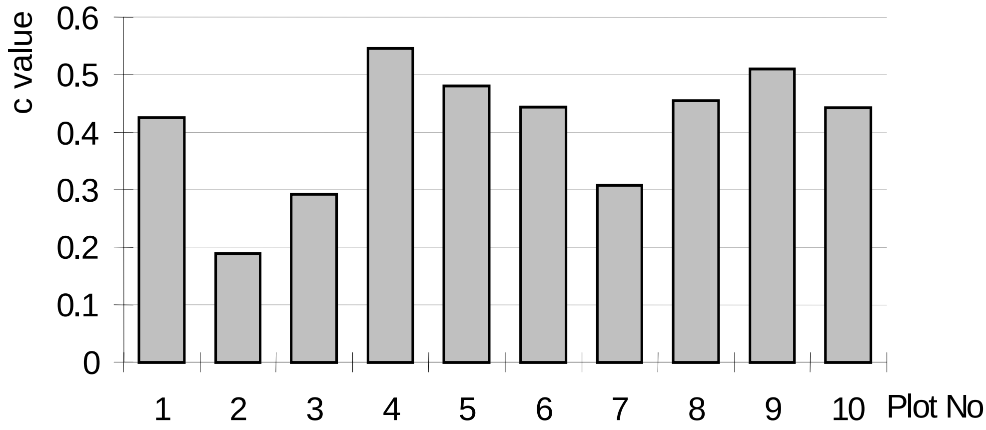

Figure C-1. The c ratio (c=a/b, where a is total number of species recorded in the five 1 m2 plots in each 10x10 m2 macro plot and b is the total number of species recorded in each of the 30x30 m2 plots (including a)) in LCG in 2000.

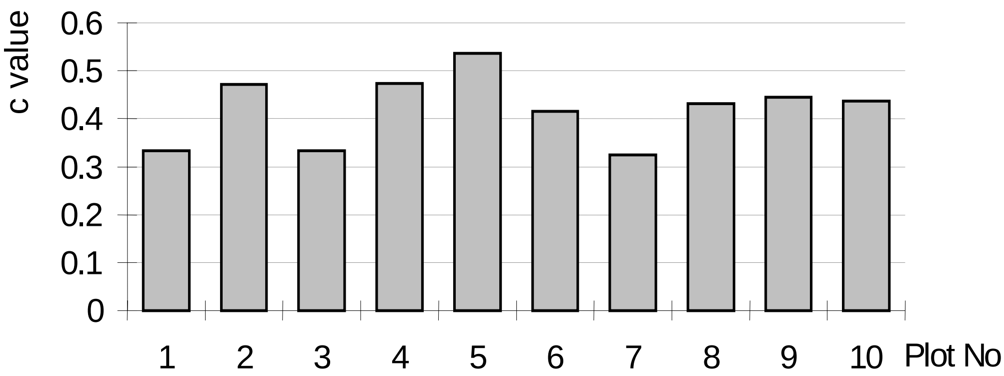

Figure C-2. The c ratio (c=a/b, where a is total number of species recorded in the five 1 m2 plots in each 10x10 m2 macro plot and b is the total number of species recorded in each of the 30x30 m2 plots (including a)) in LCG in 2002.

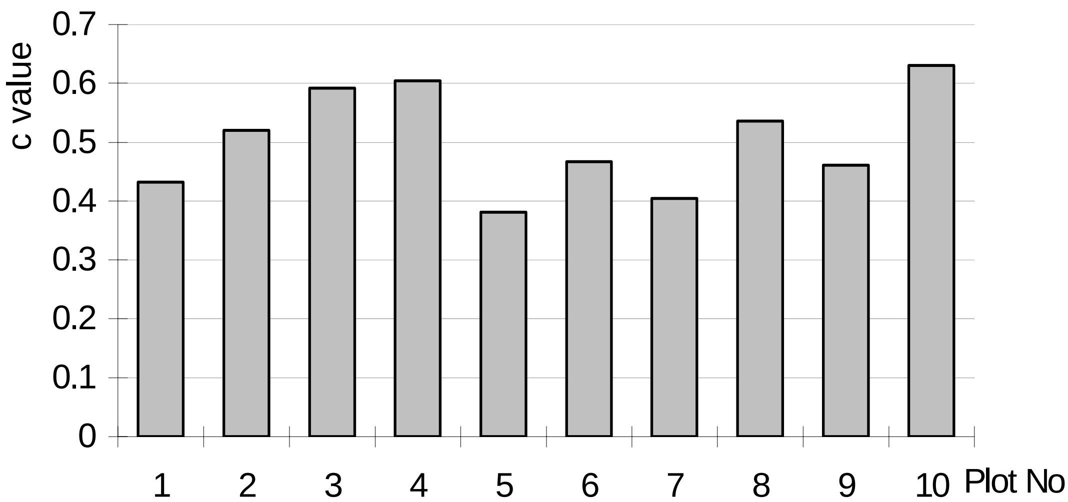

Figure C-3. The c ratio (c=a/b, where a is total number of species recorded in the five 1 m2 plots in each 10x10 m2 macro plot and b is the total number of species recorded in each of the 30x30 m2 plots (including a)) in TSP in 2000.

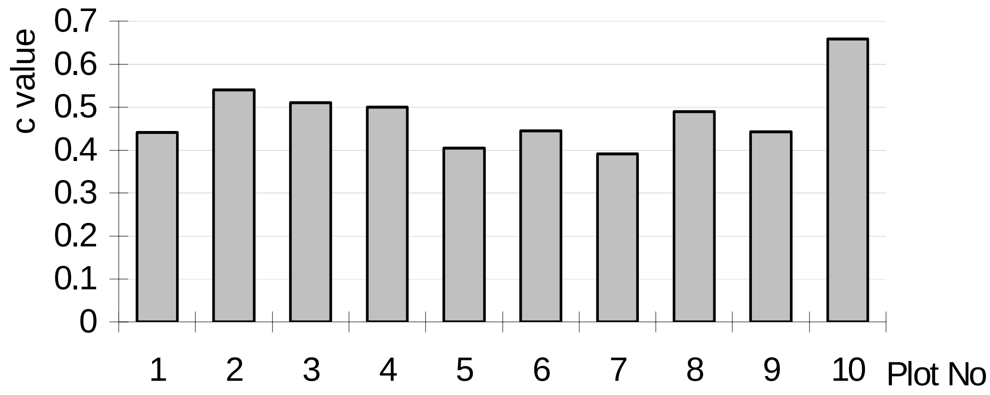

Figure C-4. The c ratio (c=a/b, where a is total number of species recorded in the five 1 m2 plots in each 10x10 m2 macro plot and b is the total number of species recorded in each of the 30x30 m2 plots (including a)) in TSP in 2002.

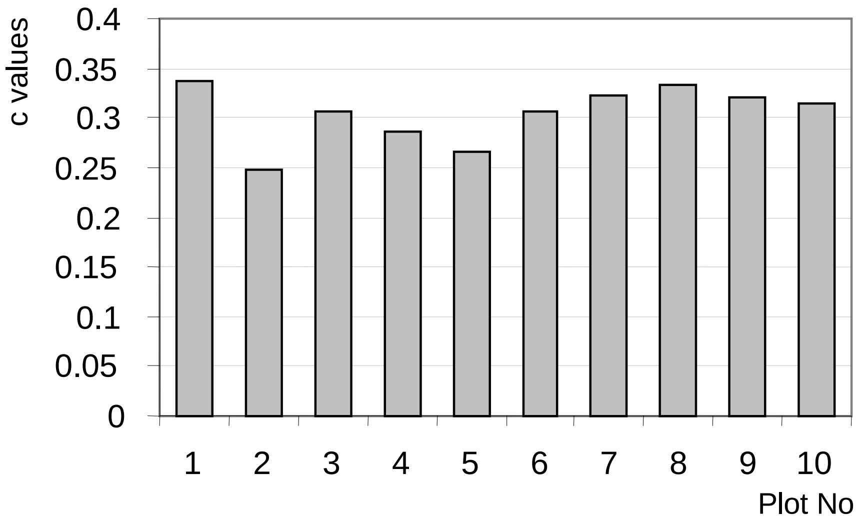

Figure. C-5. The c ratio (c=a/b, where a is total number of species recorded in the five 1 m^2 plots in each 10x10 m^2 macro plot and b is the total number of species recorded in each of the 30x30 m^2 plots (including a)) in LGS in 2001.

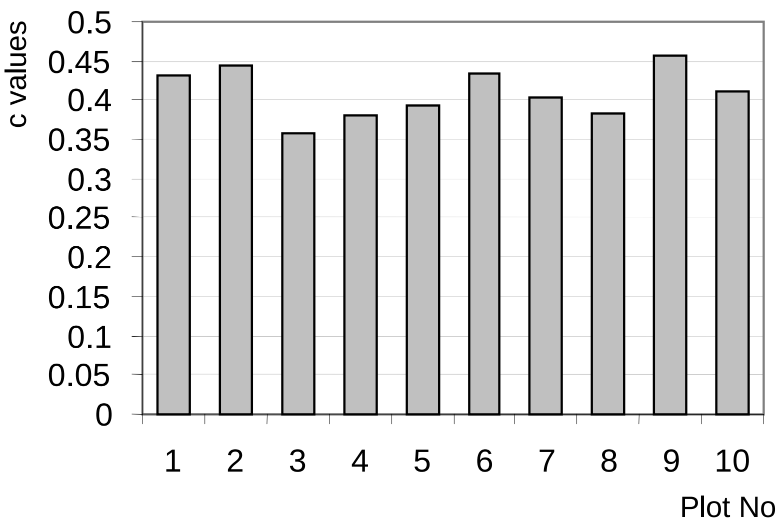

Figure C-6. The c ratio (c=a/b, where a is total number of species recorded in the five 1 m2 plots in each 10x10 m^2 macro plot and b is the total number of species recorded in each of the 30x30 m^2 plots (including a)) in LGS in 2003.

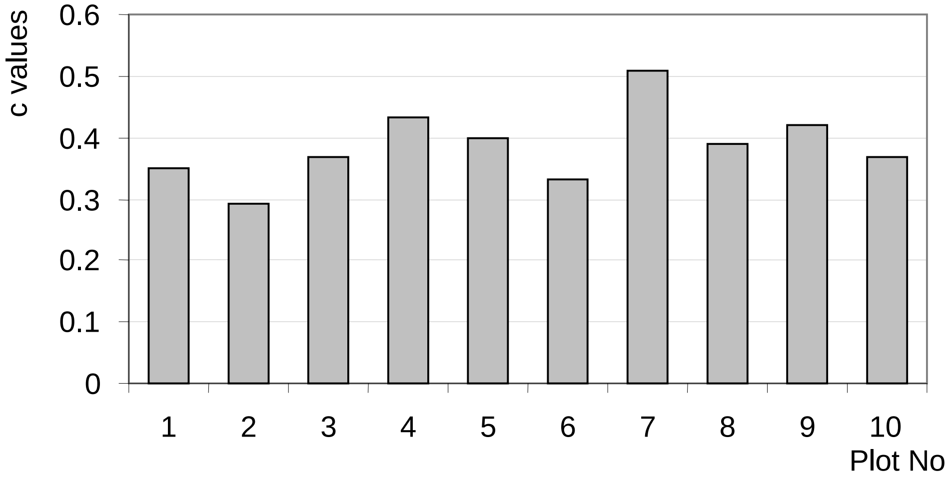

Figure C-7. The c ratio (c=a/b, where a is total number of species recorded in the five 1 m2 plots in each 10x10 m^2 macro plot and b is the total number of species recorded in each of the 30x30 m^2 plots (including a)) in CJT in 2001.

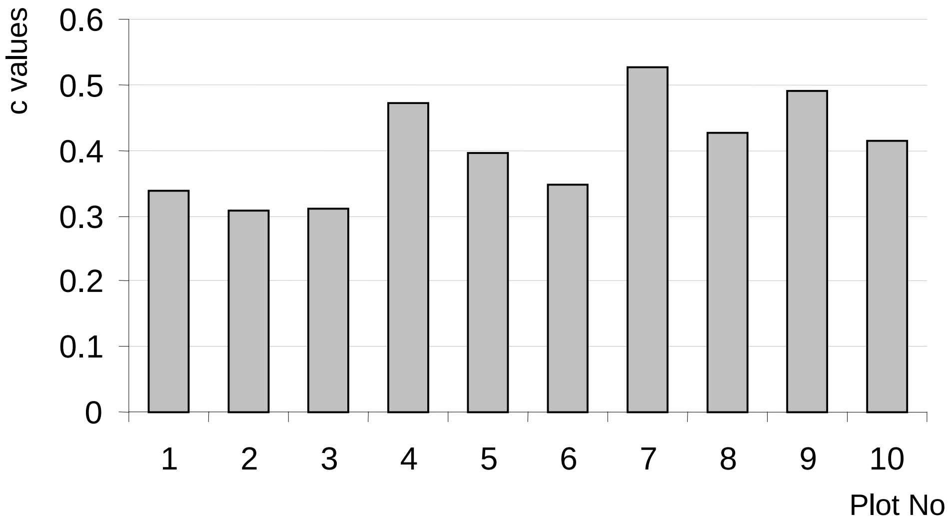

Figure C-8. The c ratio (c=a/b, where a is total number of species recorded in the five 1 m2 plots in each 10x10 m^2 macro plot and b is the total number of species recorded in each of the 30x30 m^2 plots (including a)) in CJT in 2003.

Table C-3. Kendall's nonparametric correlation coefficients τ between numbers of species and plot scores along DCA first two axes in the 5 monitoring reference areas in IMPACTS, with significance probabilities. The significance level is P 0.05. Correlations at the significance level P 0.05 are in bold face.

Reference area	**Year analyzed**	**Number of species**	**DCA1**		**DCA2**	
			τ	P	τ	P
LCG	2000	Total number	0.101	0.316	**-0.375**	**<0.0001**
		Vascular plant	**0.209**	**0.043**	**-0.223**	**0.031**
		Bryophytes	0.009	0.932	**-0.389**	**<0.0001**
TSP	2000	Total number	**-0.256**	**0.011**	-0.168	0.097
		Vascular plant	-0.085	0.408	-0.102	0.319
		Bryophytes	**-0.417**	**<0.0001**	**-0.213**	**0.045**
LGS	2001	Total number	-0.136	0.180	0.051	0.613
		Vascular plant	-0.152	0.130	0.111	0.271
		Bryophytes	-0.011	0.919	-0.130	0.210
CJT	2001	Total number	0.085	0.423	**-0.324**	**0.002**
		Vascular plant	-0.174	0.107	**-0.476**	**<0.0001**
		Bryophytes	**0.373**	**0.001**	-0.016	0.885
LXH	2002	Total number	-0.165	0.130	**-0.217**	**0.046**
		Vascular plant	-0.135	0.218	**-0.253**	**0.021**
		Bryophytes	-0.080	0.481	-0.089	0.429

Table C-4. Selected explanatory variable: affiliation to group, abbreviated code, distribution, unit of measurement, range of values and method for recording.

Variable name	Code	Unit	Explanation of method and comments
Topographic variables			
Inclination	Inclinat	º	Measured in a way that is representative for each 1-m2 plot by a clinometer compass
Maximum Inclination	IncliMax	º	Measured by a clinometer as the maximum measurable slope between two points in the sample plot, situated 10 cm apart.
Aspect Favourability	AspecFav	º	The absolute value of the difference between the plot's aspect and NNE (25 º or 425 º, whichever gives the lowest value). NNE is considered to be the most unfavorable aspect at these latitudes (Heikkinen, R.K. 1991).
Heat Index	HeatInde		Calculated according to Parker (1988), as Hi=tanα1cos α2, where α1 is the inclination and α2 is the absolute value of the difference between the plot's aspect and SSW (225 º), considered to be the most favorable aspect (Heikkinen, R.K. 1991).
Maximum Terrain Median Terrain	TerraMax TerraMed	cm	Calculated according to Nellemann & Thomsen (1994) by placing (for instance) four chains on the ground along the borders between subplots (25cm apart from the corners of the plot; two chains in each direction). After subtraction of the theoretical minimum length, 100cm. TerraMax and TerraMed mean the maximum and median of the four chain lengths, respectively.
Sum Concavity/Convexity ($1m^2$) Absolute Concavity/Convexity ($1m^2$) Variance Concavity/Convexity ($1m^2$)	ConvSum1 ConvAbs1 ConvVar1		Calculated by assigning to each plot an index value for concavity/convexity of each subplot on the following scale: -2 (concave), -1(slightly concave), 0(plane), 1(slightly convex), 2(convex). ConvSum1, ConvAbs1 and ConvVar1means summarizing the values, summarizing the absolute values and calculating the variance, respectively.
Sum Concavity/Convexity ($9m^2$) Absolute Concavity/Convexity ($9m^2$) Variance Concavity/Convexity ($9m^2$)	ConvSum9 ConvAbs9 ConvVar9		The same calculating method with concavity/convexity $1m^2$ maybe used for the 9 subplots in a 3m×3m plot with the $1\text{-}m^2$ plot in centre. ConvSum9, ConvAbs9 and ConvVar9 means summarizing the values, summarizing the absolute values and calculating the variance, respectively.

Table.C-4. (Continued)

Variable name	Code	Unit	Explanation of method and comments
Soil depth Maximum Soil Depth Median Soil Depth Minimum Soil Depth	**SoilDept** SoilDMax SoilDMed SoilDMin	cm	Calculated by measurement of the distance a steel rod can be driven into the soil in fixed positions, 10-15 cm outside the sample plot border, eight single measurements are made for each plot. SoilDMax, SoilDMed, SoilDMin means maximum soil depth, median soil depth, and minimum soil depth in all eight values, respectively.
Litter layer depth and **Soil organic layer depth** Maximum Litter layer Depth Median Litter layer Depth Minimum Litter layer Depth	LitterLD OrganiLD LitLDMax LitLDMed LitLDMin	cm	Litter layer depth should be performed in five fixed points within each 1-m2 plots, while organic layer depth should be measured just outside the border of each plot in order to avoid damage of vegetation in the plots. LitLDMax, LitLDMed, LitLDMin means maximum litter layer depth, median layer litter depth and minimum litter layer depth in all five values, respectively.
Organic layer Depth	OrganiLD	cm	Measured by preferably just outside the border of each plot in order to avoid damage of vegetation in the plots.
Soil Moisture **Soil Moisture-Short probe** **Soil Moisture-Long probe** Maximum Soil Moisture- Short probe Median Soil Moisture - short probe Minimum Soil Moisture - short probe Maximum Soil Moisture- long probe Median Soil Moisture- long probe Minimum Soil Mmoisture- long probe	SoilMois SoilMoiS SoilMorL SoiMSMax SoiMSMed SoiMSMin SoiMLMax SoiMLMed SoiMLMin	Vol.%	Measured by means of Trime-FM instrument (based on the principle of time-domain-reflectometry; Ledieu et al. 1986). Within each plot four measurements should be performed after some days without rainfall at two different depths; 0-5cm (short probe) and 0-10cm (long probe) (i.e.8 measurements in each plot). To ensure comparability, all measurements from one reference area have to be performed on the same day. SoiMSMax, SoiMSMed and SoiMSMin mean maximum soil moisture, median soil moisture and minimum soil moisture by using short probe, respectively; SoiMLMax, SoiMLMed and SoiMLMin mean maximum soil moisture, median soil moisture and minimum soil moisture by using long probe, respectively.

Table.C-4. (Continued)

Variable name	Code	Unit	Explanation of method and comments
Tree influence			
Litter Index	LitterIn		Relative amounts of litterfall over the 1-m2 plot calculated according to T. Økland (1990,1996) and R. Økland and O.Eilertsen (1993) as Litter $I_i=(d_i/cr_i)\cdot cc_i\cdot ca_i(h_i-ch_i)$, where d_i is the distance from the crown periphery to the proximal sample plot border (i.e. the side facing the stem) along the line through the plot center and the stem center for tree i, cr_i is the crown radius of tree i, measured through the plot center, cc_i is the crown is the crown cover of tree i, ca_i is the crown area of tree i within the 1-m2 plot, h_i is the tree height, and ch_i is the length along the stem from top to the point of emergence of the lowest-situated green branch whorl (in m) , respectively.
Crown Cover Index	CrowCovI		Calculated as the sum-product of canopy cover and crown area for all tree in the macro plot (25m2) surrounding the plot, as CroCovI= $_i ca_i\cdot cc_i/25$, where ca_i is crown area, cc_i is crown cover.
Relascope Coniferous Number Relascope Deciduous Number Relascope Sum trees Number	RelaConN RelaDecN RelaSumTN		Measured at breast height by use of a relascope from the lower left corner of each 1-m2 plot expression of tree density. Relascope factor 2 (the narrowest slit on the relascope) should be used. RelConNu is number of coniferous tree by using above method. RelDecNu is number of deciduous tree by using above method. RelTNSum is sum of coniferous tree and deciduous tree by using above method.
Soil chemical and physical (in A horizon)			
$pH_{H2O,\ KCL,\ CaCl2,\ BaCl2}$	$pH_{H2O,\ KCL,\ CaCl2,\ BaCl2}$		pH in water extracts of the soil (ISO10390)
Effective exchangeable Ca, Mg, K, Fe, Mn, Al	Ca, Mg, K, Fe, Mn, Al	meq/100g	$CaCl_2$-extraction and the extractant analysed for pH, Ca, Mg, K, Fe, Mn and Al by ICP, flame-atomic adsorption or emission spectroscopy (ICP/AAS/AES).
Total C	C	%	High temperature combustion to CO_2, Detection by IR adsorption (ISO 10694).
Total N	N	%	High temperature combustion to NO2, reduction to N2, Detection by thermic conductivity (ISO13878).
Effective cation exchange capacity	CEC_E	meq/100g	$CEC_E=$ $(Al^{3+}, Fe^{3+}, H^{+}, Mn^{2+}, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+})$ in $cmol_e/kg_{soil}$
Base saturation	BS	%	$\%BS=$ $(Ca^{2+}, Mg^{2+}, Na^{+}, K^{+})\cdot 100/CEC_E$
Aluminum saturation	ALS	%	$\%ALS=$ $(Al^{3+})\cdot 100/CEC_E$
SO4 adsorption	SO4	%	Extraction with PO_4.CM determination of SO_4.
Dry matter	WDM	%	Gravimetric loss after drying at 105℃(ISO11465)
Water content	WH2O	%	Weight loss after drying (ISO11465)
Loss on ignition	LOI	mmol/kg	Gravimetric loss after combustion, determined by ashing ca.1g of sample at 550℃in a muffle furnace.

Table.C-5. Main vegetation gradient (first two DCA ordination axes, corroborated by strong correlation with first two LNMDS axis) in the 5 monitoring reference areas. Axes were interpreted by calculating Kendall's τ between plot scores and environmental variables. The variables in each group most strongly correlated with the axis are indicated as follows: ++, – –: $|\tau|>0.3$, P 0.005; +, –: $|\tau|>0.2$, P 0.05. Variables in order of decreasing τ. The direction of DCA axes reversed if necessary for correlation with soil nutrient concentrations and soil pH to be negative. Main element of complex-gradient related to DCA axes in bold face. The number of 1-m2 plots is 50 for all areas, except CJT and LXH, n equal 46 and 43 respectively. Explanatory variables affiliation to group and abbreviation was showed at appendix Table.C-4. n.s.: not significant. All soil chemical/ physical variables made in A horizon..

DCA axis	Reference area	Strongly correlated variables in each group						Summary of interpretation
		Topo-graphic	Soil depth	Litter layer and Soil organic layer depth	Soil moisture	Tree influence	Soil chemical and physical	
DCA1	LiuChongGuan (LCG)	++(ConvSum 1)	+(SoilDept)	+(LitterLD)	--(SoilMoiS) -(SoilMoiL)	-- (RelaDecN) +(LitterIn, CrowCovI, RelaConN)	-- (Mn) -(Al) -(K) -(Mg) -(N) -(WH2O) -(WDM) -(LOI)	**Soil moisture/ Fine scale convexity /Soil nutrient /Tree influence** and Soil depth and Litter layer depth
	TieShanPing (TSP)	- -(Conv Abs9, ConvVar 9) -(MinInc)	++(Soil Dept)	++(LitterLD)	n.s	-(RelaConN, RelaSumN)	-(BS) -(Ca)	**Litter layer depth and Soil depth/Large scale convexity/** Tree influence/Soil nutrients
	LeiGongSHan (LGS)	++(AspecFav, Inclinat, HeatInde)	n.s	++(LitterLD, OrganiLD)	n.s	+(RelaConN, RelaSumN)	--(PH) --(H, BS, Ca, Mn, CEC) ++(AlS, Fe, Al, $SO4^{2-}$)	**Soil PH/ Soil nutrients/ Aspect favourability, Inclination, Heat index, Litter and Organic layer depth** and Tree influence
	CaiJiaTang (CJT)	++(Inclinat) - -(ConvSum 9) -(TerraMax, ConvAbs1)	n.s	++(OrganiLD)	n.s	n.s	++(ALS, Al, Fe, H)- (PH, Mn)+(SO4, K,LOI)	**High degree topographic and Organic layer depth/High exchangeable amount of some cation**/Soil PH
	LiuXiHe (LXH)	-(HeatInde)	+(SoilDept)	++(OrganiLD)	-(SoilMois)	++(RelaConN)	++(LOI)	**Organic layer depth and Number of coniferous trees and Soil loss on ignition/**Soil depth and Soil moisture

Table.C-5. (Continued)

DCA axis	Reference area	Strongly correlated variables in each group						Summary of interpretation
		Topo-graphic	Soil depth	Litter layer and Soil organic layer depth	Soil moisture	Tree influence	Soil chemical and physical	
DCA2	LiuChongGuan (LCG)	n.s	n.s	++(LitterLD)	n.s	n.s	--(pH) - (BS)	**Soil pH/ Litter depth**/Soil nutrient
	TieShanPing (TSP)	n.s	n.s	n.s	-(SoilMois)	-(RelaConN, RelaSumTN)	+(Fe)- (Na) - (Fe)+ (Mn) +(pH)	Soil moisture/Tree influence/Soil chemical variables
	LeiGongShan (LGS)	--(ConvAbs1)	n.s	n.s	-(SoilMois)	n.s	n.s	Higher degree of micro-topography/Soil moisture
	CaiJiaTang (CJT)	++(Inclinat, IncliMax) +(HeatInde) --(ConvAbs 9)	n.s	++(LitterLD, OrganiLD)	n.s	n.s	n.s	**High degree topography/ Litter and Organic layer litter depth and Plane surface**
	LiuXiHe (LXH)	++(Inclinat)	+(SoilD Min)	n.s	n.s	n.s	+(C, LOI,$SO4^{2-}$)	Inclination, Min-soil depth and Content of carbon, Loss on ignition and $SO4^{2-}$.

Table.C-6. The environmental interpretation of the main vegetation gradients in each catchment

Catchment	Main vegetation gradients
LCG	The first ordination axes separate plots on sites with low degree of micro-topography, relatively high content of exchangeable nutrients, high density of deciduous trees and soil moisture, and with thin humus layer (O soil horizon; low score) from plots on sites with the opposite characteristics (high score). The second ordination axes separated plots on sites with high soil pH and a thin litter layer to sites with the opposite characteristics. The diversity of bryophytes species decreased along the same gradient
TSP	The first ordination axes separated plots on sites with a thin litter layer depth and soil depth and a high degree of variation in topography to sites with the opposite characteristics. The diversity of bryophytes decreased along the same gradient. The second ordination axes separated plots on sites with high soil moisture (0-5 cm) to more dry sites.
LGS	The first ordination axes separated plots on sites on unfavorable aspects with low inclination, high soil moisture and high content of nutrients and high pH from plots on sites with the opposite characteristics. The second ordination axes separated plots on sites with high degree of micro topography from plots on sites with more plane surface.
CJT	The first ordination axes separated plots on sites with low inclination, low degree of micro-topography, high pH, low exchangeable content of some cation (ALS, Al, Fe, H) from plots on sites with the opposite characteristics. The number of bryophytes increased along the same gradient. The second ordination axes separated plots on sites with low inclination and low degree of topography, a low depth of the organic depth and a low litter depth, from plots on sites with the opposite characteristics. The number of vascular plants decreased along the gradient.
LXH	The first ordination axes separated plots on sites with high moisture, thin soil depth and organic layer and low density of coniferous trees, from plots on sites with the opposite characteristics. The second ordination axes separated plots on sites with high inclination from plots on sites with high inclination. The number of vascular plants decreased along the same gradient.

Table.C-7. Change in species abundance in plots in 4 reference areas during a two-year period in the time-interval 2000-2003; with Wilcoxon's one-sample Signed Ranks tests applied to the hypotheses: median change=0, against the two-tailed alternative. P=significance of increase/decrease. P 0.05 are in bold face. n –: number of plots with decrease and n+: number of plots with increase. n.s means no significant.

		LCG			**TSP**			**LGS**			**CJT**		
Species types	Species list	**n-**	**n+**	**P**	**n-**	**n+**	**P**	**n-**	**n+**	**P**	**n-**	**n+**	**P**
Vascular plants	*Achyranthes longifolia*	0	0		0	0		**3**	**21**	**0.001**	0	0	
	Actinidia fortunatii	0	0		0	0		3	5	0.121	0	0	
	Amphicarpaea edgeworthii	0	0		0	0		**0**	**8**	**0.011**	0	0	
	Antenoron filiforme	0	0		0	0		3	4	0.865	0	0	
	Aralia chinensis	0	0		5	7	0.221	0	0		0	0	
	Ardisia japonica	6	2	0.068	0	0		0	0		0	0	
	Ardisia pusilla	0	0		0	11	0.003	0	0		0	0	
	Aster ageratoides	0	0		0	0		16	15	0.636	3	3	0.832
	Camellia brevistyla	9	9	0.582	0	0		0	0		0	0	
	Camellia oleifera	0	0		4	4	0.829	0	0		0	0	
	Camellia sinensis	0	0		0	0		0	0		4	9	0.205
	Carex brunnea	0	0		0	0		0	0		**7**	**0**	**0.017**
	Carex cruciata	0	0		0	0		4	9	0.045	0	0	
	Carex harlandii	0	0		4	2	0.395	0	0		0	0	
	Castanea sequinii	5	3	0.205	0	0		0	0		0	0	
	Cayratia japonica	**5**	**0**	**0.039**	0	0		0	0		0	0	
	Celastrus vaniotii	0	0		0	0		4	2	0.244	0	0	
	Chiloscyphus heterophyllus	0	0		0	0		15	9	0.075	0	0	
	Chiloscyphus latifolius	0	0		0	0		**19**	**10**	**0.011**	0	0	
	Cinnamomum camphora	0	0		**5**	**0**	**0.042**	0	0		0	0	
	Circaea mollis	0	0		0	0		**0**	**8**	**0.011**	0	0	
	Clerodendrum cyrtophyllum	0	0		0	0		0	0		2	4	0.288
	Cunninghamia lanceolata	0	0		3	5	0.722	0	0		1	4	0.492
	Dalbergia hupeana	0	0		0	0		0	0		**1**	**6**	**0.046**
	Deyeuxia arundinacea	0	0		0	0		8	9	0.261	3	10	0.151

Table.C-7. (Continued)

		LCG			**TSP**			**LGS**			**CJT**		
Species types	Species list	**n-**	**n+**	**P**	**n-**	**n+**	**P**	**n-**	**n+**	**P**	**n-**	**n+**	**P**
Vascular plants	Dicranopteris pedata	0	0		8	9	0.635	0	0		0	0	
	Dryopteris erythrosora	6	11	0.206	9	11	0.896	0	0		0	0	
	Dryopteris fuscipes	0	0		6	5	0.475	0	0		0	0	
	Ellisiophyllum pinnatum	0	0		0	0		**0**	**13**	**0.001**	14	22	0.064
	Embelia rudis	0	0		3	3	0.339	0	0		0	0	
	Eurya loquiana	0	0		3	5	0.481	0	0		0	0	
	Gardneria multiflora	0	0		0	0		0	0		2	3	0.89

	Glechoma longituba	0	0		0	0		**13**	**0**	**0.001**	0	0	
	Gynostemma pentaphyllum	0	0		0	0		2	10	0.115	0	0	
	Hedera nepalensis	0	0		0	0		**1**	**6**	**0.041**	0	0	
	Hydrangea davidii	4	1	0.276	0	0		0	0		0	0	
	Hydrangea paniculata	0	0		0	0		**2**	**10**	**0.019**	0	0	
	Impatiens cyanantha	0	0		0	0		**3**	**17**	**0.003**	0	0	
	Impatiens dolichoceras	0	0		0	0		4	1	0.223	0	0	
	Laportea bulbifera	0	0		0	0		**0**	**6**	**0.027**	0	0	
	Ligularia intermedia	0	0		0	0		**5**	**11**	**0.043**	0	0	
	Lindera glauca	0	0		0	0		0	0		3	7	0.306
	Liriope spicata	0	0		0	0		0	0		5	7	0.873
	Litsea cubeba	**0**	**5**	**0.038**	0	0		0	0		0	0	
	Lonicera acuminata	0	0		0	0		2	4	0.206	0	0	
	Lophatherum gracile	0	0		8	6	0.376	0	0		**3**	**18**	**0.002**
	Loropetalum chinense	0	0		0	0		0	0		11	11	0.379
	Lygodium japonicum	0	0		0	0		0	0		2	5	0.075
	Maesa japonica	0	0		5	2	0.394	0	0		0	0	
	Metathelyp terishattori	0	0		0	0		**0**	**8**	**0.011**	0	0	
	Miscanthus sinensis	7	8	0.548	11	6	0.319	0	0		0	0	
	Myrsine afriana	0	0		4	2	0.739	0	0		0	0	

Table.C-7. (Continued)

		LCG			**TSP**			**LGS**			**CJT**		
Species types	Species list	**n-**	**n+**	**P**	**n-**	**n+**	**P**	**n-**	**n+**	**P**	**n-**	**n+**	**P**
Vascular plants	*Neanotis ingrata*	0	0		0	0		**0**	**6**	**0.026**	0	0	
	Nothosmyrnium japonicum	0	0		0	0		10	17	0.16	0	0	
	Oplismenus compositus	4	8	0.178	0	0		**5**	**30**	**<0.0001**	0	0	
	Oxalis griffithii	0	0		0	0		2	6	0.122	0	0	
	Paederia scandens	0	0		0	0		**0**	**7**	**0.016**	0	0	
	Paraprenanthes heptantha	0	0		0	0		2	10	0.064	0	0	
	Paraprenanthes sororia	0	0		0	0		**12**	**26**	**0.007**	0	0	
	Parathelypteris beddomei	0	0		0	0		5	3	0.725	0	0	
	Parathelypteris glanduligera	0	0		0	0		**0**	**5**	**0.039**	0	0	
	Parathelypteris japonica	4	4	0.619	4	3	0.866	0	0		0	0	
	Phylostachis heteroclada	0	0		8	2	0.083	0	0		0	0	
	Pilea japonica	0	0		0	0		21	9	0.253	0	0	
	Polygonum longisetum	0	0		0	0		**0**	**5**	**0.041**	0	0	
	Polygonum thunbergii	0	0		0	0		2	5	0.35	0	0	
	Prunus buergeriana	0	0		0	0		**0**	**5**	**0.042**	0	0	
	Pseudocyclosorus esquirolii	2	3	0.684	0	0		0	0		0	0	
	Pteridium aquilinum var.latiusculum	14	9	0.493	**11**	**1**	**0.005**	0	0		3	2	0.5
	Quercus fabri Quercus fabri	3	3	0.914	7	3	0.098	0	0		0	0	
	Randia cochinchinensis	0	0		5	2	0.125	0	0		0	0	
	Rhododendron simsii	7	7	0.975	0	0		0	0		8	9	0.667

	Rubia cordifolia	0	0		0	0		19	10	0.298	0	0	
	Rubus buergeri	**5**	**0**	**0.042**	0	0		0	0		0	0	
	Rubus columellaris	0	0		0	0		2	5	0.075	0	0	
	Rubus corchorifolius	0	0		5	2	0.396	0	0		0	0	
	Rubus irenaeus	0	0		0	0		17	15	0.918	0	0	
	Rubus lambertianus	0	0		0	0		0	0		7	5	0.842

Table.C-7. (Continued)

		LCG			**TSP**			**LGS**			**CJT**		
Species types	Species list	**n-**	**n+**	**P**	**n-**	**n+**	**P**	**n-**	**n+**	**P**	**n-**	**n+**	**P**
Vascular plants	Rubus malifolius	0	0		0	0		6	8	0.13	0	0	
	Rubus tsangii	0	0		0	0		1	4	0.492	0	0	
	Setaria palmifolia	0	0		5	2	0.063	0	0		0	0	
	Smilax china	0	0		**21**	**3**	**0.003**	0	0		6	12	0.093
	Smilax davidiana	9	6	0.621	0	0		0	0		0	0	
	Stellaria chinensis	0	0		0	0		2	6	0.139	0	0	
	Stenoloma chusanum	0	0		4	2	0.343	0	0		0	0	
	Strobilanthes triflorus	0	0		0	0		2	3	0.5	0	0	
	Symplocos lancifolia	8	10	0.860	0	0		0	0		0	0	
	Symplocos sumuntia	0	0		7	14	0.247	0	0		0	0	
	Syzygium buxifolium	0	0		4	1	0.157	0	0		0	0	
	Toxicodendron vernicifluum	0	0		0	0		**0**	**5**	**0.034**	0	0	
	Woodwardia japonica	10	8	0.554	**9**	**18**	**0.010**	0	0		3	7	0.065
Bryophytes species	*Barbella compressiramea*	0	0		0	0		1	8	0.063	0	0	
	Bazzania semiopaea	0	0		3	8	0.227	0	0		0	0	
	Brachythecium plumosum	0	0		0	0		3	6	0.21	0	0	
	Brachythecium pulchellum	0	0		0	0		10	19	0.055	0	0	
	Brotherella fauriei	0	0		0	0		1	9	0.07	0	0	
	Brotherella henonii	13	12	0.627	0	0		0	0		0	0	
	Calypogeia arguta	10	4	0.636	13	7	0.123	0	0		0	0	
	Calypogeia muellerana	1	4	0.104	0	0		0	0		4	6	0.413
	Cephalozia macounii	2	4	0.461	0	0		0	0		0	0	
	Cephaloziella microphylla	0	0		0	0		0	0		4	7	0.18
	Chiloscyphus minor	0	0		0	0		0	0		2	3	0.786
	Clastobryella cuculligera	0	0		0	0		6	4	0.152	0	0	
	Dicranodontium denudatum	3	2	0.891	0	0		0	0		0	0	

Table.C-7. (Continued)

		LCG			TSP			LGS			CJT		
Species types	Species list	**n-**	**n+**	**P**	**n-**	**n+**	**P**	**n-**	**n+**	**P**	**n-**	**n+**	**P**
Bryophytes species	*Dicranum japonicum*	**9**	**2**	**0.010**	0	0		0	0		0	0	
	Diphyscium foliosum	0	0	0	0	0		0	0		4	4	0.887
	Ditrichum pallidum	0	0	0	0	0		0	0		1	4	0.131
	Frullania hamatiloba	0	0	0	0	0		1	4	0.157	0	0	
	Herzogiella perrobusta	0	0	0	0	0		2	6	0.259	0	0	
	Heteroscyphus planus	0	0	0	2	4	0.595	0	0		0	0	
	Hypnum plumaeforme	8	1	0.056	0	0		2	4	0.596	8	9	0.364
	Isopterygium albescens	0	0	0	0	0		**2**	**11**	**0.037**	11	17	0.706
	Isopterygium fauriei	0	0	0	0	0		0	0		2	4	0.462
	Lejeuna flava	0	0	0	0	0		**1**	**12**	**0.003**	0	0	
	Leucobryum bowringii	0	0	0	**27**	**8**	**0.003**	0	0		0	0	
	Leucobryum chlorophyllosum	5	8	0.713	0	0		0	0		0	0	
	Leucobryum juniperoideum	0	0	0	0	0		**2**	**16**	**0.001**	11	16	0.346
	Metzgeria darjeelingensis	0	0	0	0	0		**4**	**14**	**0.002**	0	0	
	Pellia epiphylla	2	3	0.680	0	0		0	0		0	0	
	Plagiominum acutum	0	0	0	0	0		7	7	0.635	0	0	
	Plagiothecium cavifolium	0	0	0	0	0		6	8	0.825	0	0	
	Pseudotaxiphyllum pohliaecarpum	0	0	0	0	0		0	0		8	16	0.256
	Rhyncostegium contractum	0	0	0	0	0		10	6	0.517	0	0	
	Rhyncostegium pallidifolium	0	0	0	0	0		12	13	0.587	0	0	
	Taxiphyllum subarcuatum	16	7	0.115	**33**	**8**	**<0.0001**	0	0		0	0	
	Thuidium kanedae	0	0	0	0	0		6	9	0.15	0	0	
	Trachycystis microphylla	0	0	0	0	0		0	0		7	2	0.134

Appendix D. Technical methods

Chemical data compilation and computation
Only samples that were fully analysed (i.e. pH, UV absorbency, Al-fractions, major anions and cations and alkalinity) were used to calculate arithmetic averages, medians, quartiles and percentiles. Data on Al fractions were analysed when pH was below 5.5. Alkalinity was measured when pH was higher than 5.0. The reported value for Alkalinity is based on the titrated value subtracted for the amount of H^+ added in order to lower the pH to 4.5.

Deposition data (WO, BP, CTF and FTF) are volume weighted. Total fluxes were determined by calculating the product of the volume weighted value and the total volume of deposition.

Where alkalinity measurements were missing in samples with pH above 5.5 the bicarbonate in samples from WO, BP, CTF, FTF and SW were calculated using the sample pH and assuming pCO_2 in equilibrium with the atmosphere.

Acid Neutralizing Capacity (ANC) is calculated as the equivalent sum of base cations (Ca^{2+}+Mg^{2+}+Na^++K^+) minus the equivalent sum of strong acid anions (SO_4^{2-}+ NO_3^-+ Cl^- + Free F^-).

Crown condition assessments
Within the 10 monitoring plots, the same annually crown condition assessment activities are carried out. An overview of the methods is given in Table D-1, and is based on the methods of ICP-Forests (Anon. 1998), with a few modifications for Chinese forests:

Defoliation is defined as the loss or lack of needles/leaves. It is assessed in the upper part of the crown, and is given in percent relative to a healthy tree. It includes effects of all types of stress and damage to the tree, i.e. both of effects of naturally occurring pests and diseases, and of air pollution. The defoliation assessments are subjective, and are thus supplemented by a suite of other indicators (Table D-1), in particular defoliation type, foliage damage and needle retention. Needle retention is the number of year of living needles present on the tree and it is only estimated on pine trees. Defoliation classes from ICP-Forest are shown in Table D-2.

Table D-1. The indicators recorded during crown condition assessment, based on the methods of ICP-Forests (Anon. 1998)

Indicators			Classes
Tree	Species		
	Social status		5
	Removal / mortality		14
	Crown shading		6
	Crown visibility		4
crown	Defoliation	extent	in 1% steps
		type	7
foliage	Discoloration	extent	in 1% steps
		colour	6
		type	9
		location	6
		foliage age	3
	Needle retention		year
	Foliage size		4
	Foliage damage	extent	in 5% steps
		type	many types

<table>
<tr><td rowspan="2">Reproductive structure</td><td colspan="2">Flowering</td><td>3</td></tr>
<tr><td colspan="2">Fruiting</td><td>3</td></tr>
<tr><td rowspan="6">branches</td><td colspan="2">Secondary shoots</td><td>3</td></tr>
<tr><td rowspan="2">Dieback</td><td>extent</td><td>in 5% steps</td></tr>
<tr><td>type</td><td>6</td></tr>
<tr><td rowspan="2">Damage</td><td>type</td><td>many types</td></tr>
<tr><td>location</td><td>4</td></tr>
<tr><td colspan="2">Epiphytes</td><td>Many types, parasites separately identification</td></tr>
<tr><td rowspan="2">stem</td><td colspan="2">Damage type</td><td>many types</td></tr>
<tr><td colspan="2">Damage location</td><td>6</td></tr>
</table>

Table D-2. Defoliation classes according to UN/ECE and EU classification (Anon. 1998)

Defoliation class	Needle/leaf loss	Degree of defoliation
0	Up to 10 %	None
1	> 10 – 25 %	Slight (warning stage)
2	> 25 – 60 %	Moderate
3	> 60 - < 100 %	Severe
4	100 %	Dead

Foliar chemistry

In the four intensively monitored plots, foliage is sampled annually for foliar chemistry analyses. Foliar samples are collected every year on the main species of the plots in the autumn or anytime during the dormancy period. 3 trees are sampled on each of the intensive plots. They are outside the 30*30 m plot, belong to the predominant and dominant classes (Kraft 1-2), and be representative for the sanitary status of the plot.

The sampled foliage was taken from the upper third of crown, but not from the very first whorls; preferably between the 7th and the 15th whorl. The foliage sampled shall have been developed in full light. After the samples drying at 60-70 degrees Celsius, the mass of 100 needles is measured. The fine grounded and homogeneous samples powder were extracted with HNO3/HClO4 in Teflon-bombs, using microwave, or other methods of similar quality, then determined by ICP/AAS/AES for the total element concentration of Ca, Mg, Na, K, N, Al, P and S.

Vegetation monitoring concept

The basic principles of the ground vegetation monitoring concept used in the IMPACTS forest catchments (based on experience from monitoring of forests in Norway; for details in theory and methods, see the IMPACTS ground vegetation manual), may be summarised as:

(1) *Selection of monitoring areas must take into account the regional variation within a country in the intensity of impact factors* (e.g. airborne pollutants) and climatic and other natural gradients.

(2) *The variation along all presumably important vegetation and environmental gradients within the selected forest type must be included* in each monitoring area in similar ways.

(3) *Ground vegetation, tree variables, soil variables and other (local) environmental conditions of importance for the vegetation have to be recorded in the same, permanent marked plots.*

(4) *Identifying and understanding the complex relationships between species distributions, the total species composition and the environmental conditions* in each monitoring area are necessary as a basis for interpretation of changes in ground vegetation, and the relationship of vegetation changes to (changes in) the environment.

(5) Observed changes in nature caused by *anthropogeneous* (human-induced) factors *not of primary interest for the monitoring study* may interfere with and obscure trends related to the factors of primary interest. Change due to such factors should be kept at a *minimum*.

(6) The sampling scheme must take into consideration the purpose of the monitoring and meet *requirements for data analyses* set by relevant statistical methods (implies constraints on sample plot placement, sample plot number and sample plot size).

(7) *All plots must be re-analysed regularly* (for most forest ecosystems yearly reanalyses will cause too much damage due to trampling etc.; 5-year intervals may be an optimal compromise, as in the ground vegetation monitoring in Norway).

Ground vegetation sampling

In each of the five IMPACTS catchments "randomisation within selected blocks" was used: ten macro sample plots, each 10x10 m, were placed subjectively in order to represent the variation along presumably important ecological gradients (in aspect, nutrient conditions, light supply, topographic conditions, soil moisture etc; see e.g. T. Økland 1996). Each 10x 10 m macro sample plot was positioned in the centre of one 30x30 m extended macro plot (used for recording of tree parameters). Five 1-m^2 sample plots were placed at random in each macro sample plot, resulting in 50 1-m^2 sample plots in each catchment.

Two abundance measures were used: (1) *Frequency in subplot*, by which each of the 1-m^2 plots (50 plots in each reference area) is divided into 16 subplots of equal size. Presence/absence of all species was recorded for each subplot, and frequency in subplots calculated for each species. A species was recorded as present when covering a subplot. (2) *Percentage cover*, as estimated visually for each species in each 1-m^2 plot.

Several tree layer, environmental and other explanatory variables (see manual for details) have been recorded in or just outside the 1-m^2 plots and in the 10x10 m macro plots: (1) topographical variables, (2) tree influence variables and (3) soil physical and chemical variables (the latter measured both in A and B1 soil horizons).

Statistical analyses for ground vegetation

Ordination methods were applied to *initial data matrices* (subplot frequencies for all species recorded in all plots at establishment) from each catchment to summarise main vegetation gradients. Two ordination methods were used in parallel, as recommended by R. Økland (1990): Detrended Correspondence Analysis, DCA (Hill 1979; Hill & Gauch 1980) and Local Non-metric Multi-dimentional Scaling, LNMDS (Kruskal et al. 1973; Minchin 1987). Kendall's non-parametric correlation coefficient τ (cf. Sokal & Rohlf 1995) between corresponding plot scores along DCA and LNMDS axes was calculated as a measure of concordance; strong correlations between axes in the two ordinations indicated axes that expressed 'true' vegetation structure.

Ordination axes are vegetation gradients. In order to elucidate the complex relationships between species composition and environmental conditions, these gradients must be interpreted for each catchment by means of the measured explanatory variables. Ecocline [gradients in vegetation and environmental factors] interpretations of the ordination axes were made by calculation of Kendall's τ between plot scores along DCA and/or LNMDS axes and explanatory variables.

Analyses of vegetation gradients with environmental interpretation are exemplified by analyses of data for the all five catchments.

Statistical methods are also used to test if vegetation changes from one time-point of analysis to the next are significantly larger than expected by chance (Wilcoxon´s Signed Ranks test for one sample;

cf. Sokal & Rohlf 1995). Statistical tests of vegetation changes are exemplified by analyses of data from the four (LCG, TSP, LGS, CJT)catchments below.

Ground vegetation change in all four catchments from establishment year to the first re-analysis two years latter was analysed by testing the hypothesis of no change (median change = 0, against the two-tailed alternative; Wilcoxon's test. Change in three variables was tested:

(1) Abundance (subplot frequency) change for each species of vascular plants and bryophytes with observed abundance change in ≥ 5 plots.
(2) The total number of species, the number of vascular plant species, and the number of bryophyte species, respectively, in each 1-m^2 plot.
(3) Change in species composition, as given by plot scores along environmentally interpreted ordination axes; i.e displacement of plots in DCA ordination space for ordination of 100 sample plots (the 50 plots analysed at establishment and the 50 reanalysed plots).