C-4 Quantitative Analysis of Terrestrial Ecosystem Decline Related to Acidic/Oxidative Substances (Abstract of the Final Report)

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(1) Studies on the state of and the monitoring methodology for acid deposition in the declining terrestrial ecosystem

Ozone was monitored using a battery-driven ozone sensor near the top of Mt. Mae-Shirane in Oku-Nikko region where the severe forest decline was observed. The maximum ozone concentration was about 90 ppbv during the summer 1999 when fine weather and south-east winds prevailed. This suggests that high concentration of ozone was transported from Tokyo metropolitan area and reached Nikko, which may cause the damage to the plant. Peroxides were measured at the Oku-Nikko observation site, which was situated at the foot of Mt. Mae-Shirane. Peaks of H_2O_2 were often observed in the late afternoon and at night and H_2O_2 concentration was strongly correlated with ozone. The forest exposure to H_2O_2 in Oku-Nikko region during the summer 2000 was estimated from the ozone concentration and was about 300 ppbv h. High concentration of ozone leads to the production of peroxides and may cause the damage to the plants. Ozone deposition velocity to trees was measured by the Bowen ratio method and by the wind profile method. Deposition velocities of ozone and sulfur dioxide onto soil were also measured by the flow reactor method. In the Oshiba-Kogen field, Concentrations of ozone and nitrogen oxides were measured above and below the canopy of a red pine forest. The ozone concentration in summer showed a diurnal variation pattern parallel to the solar radiation intensity, and was found to be correlated with the NO and NO_2 concentrations with slight temporal delays. The vertical ozone profile revealed a broad maximum below the canopy and a distinct minimum in the leaf layer, and there was found a decreasing upward gradient above the canopy. Vertical temperature profile exhibited a situation favorable for the ozone formation below the canopy. From these observations, it was concluded that photochemical ozone formation was going on both above and below the canopy. Two important implications resulting from this study are

1) a forest can be a source of ozone and thus may contribute to the rise of the tropospheric base concentration, and 2) deposition of ozone to trees can take place not only from outside but also from inside of a forest. In autumn, however, the ozone concentration minimum in the leaf layer was not notable, suggesting that the deposition or removal was dependent on temperature. Peroxides flux in the Oshiba-Kogen field was also measured. The correlation between the fluxes of peroxides and a-pinene shows that H_2O_2 was deposited into the forest and methylhydroperoxide was produced and emitted from the forest. Several kinds of plants were exposed to H_2O_2. In all cases, the damage to the plants was observed.

(2) The analysis of tree decline in terrestrial ecosystems based on nutrient dynamics and damages by disease and pest

In Oku-Nikko, where some trees are declining, soil chemical properties varied within the range of those of podozolic soils and dark brown forest soils developed in sub-alpine forests. However, the data of soil sulfate adsorption suggested that sulfate deposition in a forest-declining area of Mt. Omanako was higher than those in the other areas.

Tree leaves collected in Oku-Nikko contained more nitrogen, and less magnesium than the leaves collected in other sub-alpine forests.

Root system development of *Tsuga diversifolia* was not good in declining area. Nutrient concentrations in needles, non-ectomycorrhizal roots, and ectomycorrhiza of healthy and declining trees were analyzed. The concentrations of nitrogen, phosphorous, and calcium in needles, and calcium in ectomycorrhizas and non-mycorrhzal roots decreased in declining trees.

Trap log method showed existence of *Armillaria* on almost all the examined trees in regardless to decline level of the trees. *Armillaria* in this area was assumed to be secondary pathogen or saprophyte of *Betula ermanii.* Result of the inoculation test indicated that *Armillaria* in the *B. ermanii* forest has ability to infect *B. ermanii* according to environmental conditions.

Ophiostoma species and *Ceratocystis laricicola* were isolated from bark beetles and coniferous trees infested with the beetles. The fungi and the bark beetles appeared to be at least partially responsible for mortality of the conifers in Oku-Nikko.

Rust flora in Oku-Nikko might be affected by change of host plant flora influenced by some factors.

Ammonium nitrate application on the seedlings of *Salix* increased the number of uredinia of *Melampsora epiphylla,* but there were no significant effects of nitrogen application on the size of lesion of *Ophiostoma subalpinum* and *Ceratocystis laricicola* on the seedlings of *Abies* and *Larix.*

Nitric acid or ammonium nitrate of nitrogen compounds were applied as artificial

acid precipitation to the soil of 19-year-old *Cryptomeria japonica* plantation. The nitrogen compound applications caused the decrease of soil pH. Nitrate and calcium in the soil water of the plot of ammonium nitrate application and the plot of nitric acid application increased. The nitrogen compounds in the needles of *C. japonica* also increased. The influence of applications on the tree growth was not clear.

Ammonium nitrate and nitric acid application increased fine root biomass and active biomass of arbuscular mycorrhizal fungi estimated from ergosterol of mycorrhiza. Total bacteria and ammonium-oxidizing bacteria increased from 1998 to 2001 in ammonium nitrate plot. Total bacteria also increased in nitric acid plot.

(3) Evaluation on the effects of environmental factors on eco-physiological characteristics of plants grown in the forest declined region

The trees growing on the NW-facing slope are relatively healthy, but those growing on the SE-facing slope are declining. In the summer, the leaves of the trees growing on the SE-facing slope showed severe eating injuries of leaf insects, as compared to the leaves of the trees growing on the NW-facing slope. Individual leaf area and leaf number per tree of the trees growing on the SE-facing slope were less than those of the trees growing on the NW-facing slope. The leaf yellowing, defoliation, and reduction in the concentrations of chlorophyll, Rubisco and total soluble protein of the leaves became earlier in the trees growing on the SE-facing slope compared to the trees growing on the NW-facing slope. Soil pH on the SE-facing slope was significantly higher than that on the NW-facing slope. The accumulation of Mn and Al were not observed in the soil and leaves of the trees growing on the SE-facing slope.

Needle chlorophyll concentrations of declining *Abies veitchii* were significantly less than those of healthy trees. Although needle concentrations of Rubisco and total soluble protein of the declining trees were not significantly different between declining and healthy trees, needle K concentration of declining trees was significantly less than that of healthy trees.

Based on the results obtained from this field survey, decline of *Betula ermanii* growing on the SE-facing slope around Mt. Mae-Shirane cannot be explained by soil acidification and nutrient deficiency of soil and leaves. Therefore, we must investigate the relationships between ecophysiological characteristics and atmospheric and soil environment such as air pollutants, drought and nitrogen status. Because needle K concentration of declining *Abies veitchii* was significantly less than that of healthy trees and generally acid rain and fog stimulate leaching of elements from needles, we must investigate the effects of acid deposition such as acid fog on nutrient status of this tree species.

(4) Quantitative evaluation of effects of acid deposition on a fresh water environment

In watershed of River Toyama-sawa, the increase in the ionic concentrations of Na^+ and Ca^{2+} of river water and groundwater were observed through the winter season (from December to February). It was considered that the concentrations of ionic components

derived from soil and rock increased because quantity of infiltration of meteoric water decreased as a result of deposition of snow. Generally, major ions are lost from the snowpack at differing rates during melting, a process known as *preferential elution*. In this research, the process was not observed, however, dilution of ionic concentrations of river water and groundwater caused by snowmelt were observed. The water quality of Goshiki-sawa showed similar trend. Water quality of River Toyama-sawa and Goshiki-sawa did not have relevance to flux, excluding winter season. In September 2001, ionic concentrations of River Toyama-sawa and Goshiki-sawa declined as a result of heavy rain by the typhoon No.15; the total precipitation amount was 891 mm.

It is considered that almost all Cl^- that dissolved in river water and groundwater deposited from atmosphere. Then, in this research, we assumed that all dissolved Cl^- in fresh water in the catchment deposit from atmosphere. With this assumption, we compared the water quality of two rivers and groundwater with precipitation using the ratio of SO_4^{2-}/Cl^- and NO_3^-/Cl^- (equivalence ratio). According to the results, the ratio of SO_4^{2-}/Cl^- in River Toyama-sawa was similar to the ratio in the precipitation. However, this ratio in River Goshiki-sawa was very higher than that in precipitation. It is assumed that the high concentration of SO_4^{2-} in Rive Goshiki-sawa is affected by volcanic activity because the river water has very high electric conductivity. On the contrary, the ratio of NO_3^-/Cl^- in Rive Goshiki-sawa showed similar value to precipitation. However, this ratio in River Toyama-sawa was higher than that in precipitation. Especially the value of groundwater was higher than that of precipitation. Water soluble anions in soil showed the similar trend. In River Toyama-sawa watershed, it is assumed that NO_3^- derives from atmospheric deposition because the river water has low electric conductivity; this area is not affected by volcanic activity.

(5) Integrated analysis of material cycle in the forest ecosystems with the catchment scale model

We evaluated the external input of acidic substances as well as the internal biogeochemical cycles mainly of base cations and nitrogen in Sotoyamazawa catchment in Nikko. Field surveys were made at Maeshirane (2300 m of elevation) where birch forest had declined, and at Yumihari (1420 m), the sound deciduous forest from July to October in 2000 and June to October 2001. Based on the data on element fluxes (Table 1), the following results were obtained. 1) Regarding the acidic deposition in Maeshirane, total nitrogen deposition was as much as Yumihari but ammonium dry deposition was higher. Concentrations of O_3 and SO_2 were almost twice higher than Yumihari. 2) Trees are still growing at Maeshirane and N accumulation rate by net plant growth per unit area was 70-80 % of Yumihari. Base cations are tight and BC flows through canopy leaching (LE), litterfall (LF) and discharge from soil layer (DS) were quite small at Maeshirane. 3) Proton budget due to internal biogeochemical cycle was much larger than external proton in put at Yumihari. At Maeshirane, on the contrary, internal cycle was small and relative contribution of external proton was larger. Maeshirane must be sensitive to the changes

of external acid input (Fig.1). 4) Processes such as mineralization of organic matter, nitrification and plant uptake, which substantially regulate the nitrogen and base cation cycles, should be properly incorporated into the catchment model.

Table 1 Nitrogen and base cation budget in Nikko sites

	Nitrogen							Base cations (K+Mg+Ca)							
	WD	DD	LF	GU	UP	SS	DS	WD	DD	LE	LF	GU	UP	SS	DS
Yumihari	128	-62	463	118	580	589	75	78		153	385	101	639	640	233
Maeshirane	33	42	139	94	233	165	7	12	6	37	26	81	145	118	28

WD:wet deposition, DD:dry deposition, LE:canopy leaching, LF: litterfall, GU:growth uptake
UP:plant uptake, SS:supply from SOM, soil minerals, DS:discharge from soil layer

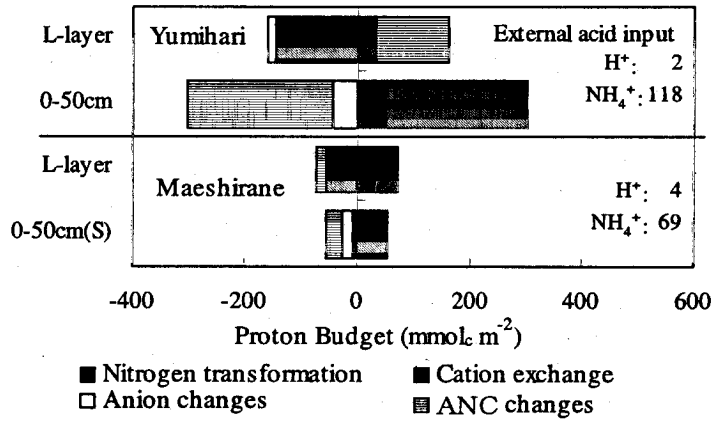

Fig.1 Progon budget in Nikko sites and external acid input

We also carried out the field experiments manipulating the nitrogen input at Kannondai and Yasato in Ibaraki Prefecture and at Takayama in Gifu Prefecture. Two years manipulation did not have any significant effects on the nitrate concentration in soil solution nor N_2O emission for forest floor at Ibaraki sites. Large amounts of nitrogen were cycling internally in the plant-soil system and external nitrogen input has little effect on the cycle. At coniferous forest in Takayama, addition of nitrogen (+40kg N $ha^{-1}y^{-1}$) significantly increased the nitrate concentration in soil solution up to 1 m depth in the 2nd and the 3rd year in the same manner as some of the NITREX sites in Europe. Further study will be necessary to derive the relation between nitrogen saturation processes and internal cycles in ecosystems.

(6) Development of a network of researchers on terrestrial ecosystem decline

1) Through the Workshop, network of technologists/researchers on terrestrial ecosystem was established. In the Workshop, sensitivity of plants, microbiological processes relating to acid deposition, and elements dynamics in terrestrial ecosystems, were clarified as subjects to be studied intensively. Need of establishment of international network on specialists was recommended in the workshop summary, and

the Network of Soil and Vegetation Specialists was established as an official function of Acid Deposition Monitoring Network in East Asia (EANET).

2) The methodologies and the study field for measuring dry deposition were decided. Based on this preliminary study, joint research was started and have been continued.

3) The present situations of studies on terrestrial ecosystem in Malaysia, Thailand, Philippines, and Viet Nam were clarified. In Malaysia, some research activities on this field have already been promoted in University of Putra Malaysia. In Thailand, PCD have started the joint study on dry deposition flux with Acid Deposition and Oxidant Research Center (ADORC). In Philippines, University of the Philippines, Los Banos, has the appropriate experimental forests and the relevant experience for the future study. In Viet Nam, specialists on this field were limited and detailed study has not started, yet.

4) As one of the most important issues on terrestrial ecosystem decline in East Asia, sensitivity of Asian plant was identified. In Mongolia, need of the preliminary study was recommended. In Philippines, the possibility of future joint study was suggested.

(7) Research on decline of *Betula ermanii* related to some environmental factors

We examined the present situation of growth (height, diameter at breast height (DBH), stem volume and stand density) of *Betula ermanii*, ozone concentration and soil water/fertility status from June to October 2001, and estimated the forest decline level at southeast and northwest slopes near the top of Mt. Maesirane to explicate the possible cause of forest decline there. The remarkable difference of tree growth was observed between two plots, height, DBH, stem volume, stand density were lower at southeast slope than those at northwest slope. The ozone concentration was significantly higher at southeast slope than that at northwest one, and the main direction of wind was southeast, so wind stress was also higher at southeast slope. Therefore these environmental factors are considered to cause the difference of *Betula ermanii* growth between southeast and northwest slopes. The deficiency of elements, however, such as K, Ca and Mg were not observed in the soil and leaves of the trees growing on the southeast slope.

(8) Reconnaissance study on the Water Quality of Miomotegawa River In Niigata Prefecture for the evaluation of the impacts of acid pollution

We decided Miomotegawa river was the object of our investigation since it is one of the most important salmon river in Japan. A great number of salmons have returned to the river, and it was expected to contain relatively lower cation concentrations since granite is widely distributed in the river catchment area The concentration of calcium and magnesium were as less than a half of that of other major rivers. The concentration of analyzed parameters indicating water quality effect on salmons, NO_3, SO_4 and NH_4, were 1.37, 4.08 and 0.01mg/l, respectively. Most of parameters of down stream were greater concentration than that of upper stream.