B-12.2.2 Effects of the global warming on the vegetation on a humid tropical mountain

Contact person: Kanehiro Kitayama
Overseas Forest-Environment Research Team, The Japanese
Forestry and Forest Products Research Institute,
1 Matsunosato, Kukizaki, Inashiki-gun, Ibaraki 305, Japan
Tel, +81 298 73 3211 ext. 248; Fax, +81 298 73 1541
E-mail, kanehiro@ffpri.affrc.go.jp

Total budget for FY1995: 9,241,000 Yen

Abstract: Soil nitrogen mineralization rates and leaf longevity of woody species were investigated at various altitudes on a wet slope of Mount Kinabalu, Borneo. N mineralization rates of the soils derived from sedimentary and ultrabasic rocks significantly changed as a function of temperature. An estimated temperature coefficient was 1.7 for sedimentary soil,but was much less for ultrabasic soil. It appears that effects of global warming are contrasting between the substrates with less effects on ultrabasic soils. It also appears that effects are greater in warmer lowland than in cooler upland.Nearly all trees were evergreen on Kinabalu. Leaf longevity, however, greatly varied among species from >1yr to <1yr at a given altitude. The longevity of the wide-ranging species Schima wallichii increased with altitude. These trends in longevity were consistent with a prediction model.

Keywords: net N mineralization potential, temperature coefficient, tropical mountain, phenology, leaf longevity

SECTION 1 EFFECTS OF NET SOIL NITROGEN MINERALIZATION POTENTIAL ON A TROPICAL MOUNTAIN

1. Introduction

Soil nitrogen supplying power is determined by biogeochemical processes, and thus is dependant on temperature if other factors do not limit. We investigated net soil nitrogen transformation rates using an incubation technique in a matrix of five elevations (800, 1400, 2100, 2700 and 3100m) and two geological substrates (sedimentary versus ultrabasic rock) on Mount Kinabalu, Borneo. We used the substrate as a surrogate of the level of available nutrients (rich sediment versus poor and potentially toxic ultrabasic), and the altitudes as a surrogate of temperature. Thus, the matrix represents temperature versus nutrient effects and results of this analysis will simulate patterns of net soil nitrogen mineralization potential with increasing temperature on two contrasting substrates.

2. Methods

Four 20 to 50 m transects were laid out, each from a random point, in each of the ten sites. We collected ten 15-cm-deep soil cores by forcing a core sampler systematically along each transect, and combined the ten cores into one composite. The collected samples were returned to the laboratory, and immediately stored in a refrigerator.

A subsample of each composite was ovendried at 105°C for 48h to determine gravimetric water content. The rest of each composite was divided into four subsamples and c. 10 g (fresh weight) of each subsample was weighted to nearest mg, and deposited into a 10 x 15 cm sealable polyethylene bag.

The first set of subsamples was used for initial extraction, the second set to determine net N transformation rate in each site (called "in-situ" treatment), the third set to investigate influences of substrate on the rate by placing all under the same temperature ("common-site" treatment), and the fourth set to investigate the influences of phosphate fertilization on the rate ("phosphate" treatment).

Initial extraction: One of the four subsamples immediately received 100 ml 1.5 N KCl solution to extract initial NO_3 and NH_4, and extractable Ca, Mg and Mn. The soil-solution mixture was vigorously shaken for 0.5 hr, equilibrated for 12 hr, and filtered through a Whatman No. 2 filter paper. To prevent contamination of the extract by inorganic N contained in the filter paper, we first rinsed the filter paper by filtering c. 50 ml blank KCl which was discarded. The second filtrate was immediately stored in a refrigerator for up to 14 days.

In-situ treatment: Another set of subsamples, loosely sealed to permit aeration, were returned to their original sites. The samples in each site were kept in a large untied polyethylene bag to protect from rain, and buried under litter.

Common-site treatment: Another set of subsamples were incubated in the dark in the laboratory at 1700 m. The samples were also loosely sealed, and collectively kept in a large polyethylene bag with water-saturated cotton to keep soil-moisture condition constant. Air temperature was daily monitored with a max-min thermometer calibrated against a standard thermometer. The incubation site had a mean air temperature of 20.5°C (±0.4°C).

Phosphate treatment: One set of subsamples received phosphate at the rate of 50 μg P per 1 g oven-dry soil in the form of NaH_2PO_4 solution. The NaH_2PO_4 solution was adjusted to an appropriate concentration (c. 0.01 N) so that the applied solution was always less than 0.5 ml so as not to saturate the soils. The phosphate treated samples were incubated in the same place as the common-site samples. Therefore the common-site samples also served as a control for the phosphate treatment.

After exactly 10 days of incubation, all samples were collected and sent to the laboratory, and immediately stored in a refrigerator to suppress soil-microbial activities. All samples were extracted for final NO_3 and NH_4 within 48 hr using the same method as the initial extraction.

NO_3- and NH_4-N concentrations were determined colorimetrically on each extract using a Burkard SFA-2 autoanalyzer. Net nitrification rate was calculated as final minus initial NO_3-N; net mineralization rate as final minus initial $(NO_3 + NH_4)$-N.

The concentrations of exchangeable Ca, Mg and Mn were also determined on each initial extract by atomic absorption spectrometry. Organic C was determined on fresh soil by the Walkley-Black wet digestion method. Total N was digested by the micro Kjeldahl procedure with concentrated sulfuric acid, and determined colorimetrically on the autoanalyzer. Soluble P was extracted with hydrochloric-ammonium fluoride solution, and determined colorimetrically. Each chemical analysis included two replicates of a known soil sample which served as an internal standard. Soil pH was measured on a 1 : 1 fresh soil to deionized water solution.

3. Results

Results of the soil chemical analyses are shown in Tables 1. Gravimetric water content increased from 27% at 800 m to 70% at 2100 m, and then declined upslope on sedimentary rock. A middle-slope increase in water content was also noticeable on ultrabasic rock, but the magnitude of variation was much narrower.

pH of topsoils (15 cm) was acidic across altitudes on sedimentary rock, and weakly acidic on ultrabasic rock (Table 1). Organic matter accumulated at middle altitudes (2100 and 2700 m) on sedimentary rock as indicated by the high concentrations of organic C and total N (Table 1). A high C/N value in excess of 25 was found at 2100 m on sedimentary rock. By contrast, the concentrations of organic C and total N were consistently low across altitudes on ultrabasic rock. Soluble-P was extremely low in ultrabasic soils across altitudes; that of sedimentary soils increased from low to middle altitudes and declined towards the highest elevation.

The altitudinal pattern in the initial pool of inorganic N was contrasting between NH_4 and NO_3; NH_4 concentration showed a highest value at a middle elevation on both substrates, while NO_3 showed either the reversed pattern of NH_4 (on sedimentary) or a rapid reduction with altitude (on ultrabasic) (Table 1).

In-situ net soil N mineralization rate on a weight basis was significantly ($P<0.05$, one-way analysis of variance) higher in sedimentary than in ultrabasic soils at 800, 1400 and 3100 m; the rate was not significantly different between the substrates at 2100 and 2700 m (Table 2).

Net mineralization rates of the soils which were collected from different altitudes and incubated at the constant temperature of 20.5 °C (the common-site treatment) were contrasting between sedimentary and ultrabasic rocks (Table 3). Although the mean mineralization rates of the soils from sedimentary rock were variable, they were not significantly different among altitudes of origin ($p=0.05$, Tukey's HSD). By contrast, the mineralization rates of ultrabasic soils were significantly different among altitudes and the rates decreased with increasing altitude more or less following the pattern of in-situ mineralization rates (cf. Table 2). Thus, influences of substrate on soil N transformation were not significant on sedimentary rock, whereas the mineralization rate was inherently determined by substrate on ultrabasic rock.

P fertilization reduced both net nitrification and mineralization rates in almost all cases (by 3 to 6 $\mu g g^{-1} 10 d^{-1}$ in the case of mineralization) (Table 4). The difference between P-applied versus control (i.e common-site) soils in net mineralization rate was statistically significant ($p \leq 0.05$, paired T test) at all altitudes in ultrabasic soils except at 1400 m; however, the statistical significance P at 1400 m was 0.08 and, thus, the reduction was also marginally significant. By contrast, a significant reduction occurred only at 800 m on sedimentary rock.

4. Discussion

The concentrations of soil organic C and total N were distinctly elevated at 2100-2700 m on sedimentary rock, but nearly constant across altitudes on ultrabasic rock. Strong moisture effects through mid-slope cloud were suggested to suppress organic matter decomposition on sedimentary rock, whereas moisture effects appeared to be less on ultrabasic rock probably due to the high water permeability generic to the soils. An in-situ incubation experiment showed that net mineralization rates decreased with elevation on both substrates: however, the reduction was linear across altitudes on ultrabasic rock, whereas its pattern was depressed at middle elevations on sedimentary rock, again suggesting strong moisture effects on sedimentary rock. The in-situ rates were significantly ($P<0.05$) greater on sedimentary than on ultrabasic rock under the same temperature (altitude) except for those elevations at which cloud occurred. The net mineralization rates of the soils collected from different elevations but incubated in the same condition were statistically invariable ($P>0.05$) among altitudes of origin on sedimentary rock, whereas variable ($P \leq 0.05$) on ultrabasic rock; the net rates on ultrabasic rock mimicked the altitudinal pattern of the in-situ rates. Thus, temperature more strongly regulated net N mineralization on sedimentary rock, whereas inherent soil quality more strongly regulated mineralization on ultrabasic rock. Fertilization of phosphate at the rate of 50-ppm P per g dry soil resulted in significant ($P \leq 0.05$) net negative mineralization at nearly all altitudes on ultrabasic rock, but only at 800 m on sedimentary rock. It appeared that soil microbes responded to added P and immobilized N in all ultrabasic sites, indicating that P might be limiting soil N transformation rate (thus other ecological processes) more strongly on ultrabasic than on sedimentary rock. Our results clearly show that temperature controls net nitrogen mineralization potentials and that the effects of temperature are modified by moisture and mineral nutrients reflecting the substrate difference.

Table 1. Soil pH (H^2O), and concentrations of organic-C, total-N, easily soluble P, inorganic N (NH_4-N and NO_3-N) and exchangeable cations on an oven-dry weight basis. Values are means (±sd). 'Sed' denotes sedimentary rock sites, and 'Ult' denotes ultrabasic rock sites.

Alt (m)	800	1400	2100	2700	3100
pH(H_2O)					
Sed	4.1(.1)	3.6(.1)	3.1(.2)	3.4(.2)	4.9(.1)
Ult	4.5(.2)	4.9(.1)	5.4(.1)	5.1(.1)	5.34(.1)
Organic-C (%)					
Sed	2.9(.1)	10.6(3.8)	20.0(4.3)	17.7(4.0)	8.6(2.1)
Ult	2.4(.2)	4.6(.04)	3.4(.3)	3.5(.6)	3.5(.2)
Total-N (%)					
Sed	0.21(.01)	0.63(.18)	0.77(.16)	0.92(.18)	0.60(.02)
Ult	0.21(.02)	0.33(.02)	0.28(.02)	0.35(.02)	0.26(.02)
C/N ratio					
Sed	13.8	16.7	26.0	19.2	14.3
Ult	11.4	13.9	12.1	9.9	13.3
NH_4-N (μgg^{-1})					
Sed	3.9(0.6)	28.7(4.9)	27.9(12.4)	29.9(14.3)	4.8(1.5)
Ult	8.9(2.1)	16.3(3.8)	26.6(3.8)	7.3(1.5)	5.2(.7)
NO_3-N (μgg^{-1})					
Sed	10.2(1.8)	2.0(2.0)	nd	2.9(1.5)	8.4(.9)
Ult	7.2(5.6)	0.2(.1)	0.8(.7)	0.8(1.1)	nd
Soluble P (μgg^{-1})					
Sed	1.56(.56)	4.70(1.62)	8.85(1.63)	20.93(4.46)	6.23(.68)
Ult	1.18(.45)	.41(.08)	.84(.06)	1.89(1.15)	.80(.42)
Ex. Ca (μgg^{-1})					
Sed	17(10)	87(23)	79(47)	61(18)	734(336)
Ult	29(12)	128(65)	630(132)	299(147)	375(147)
Ex. Mg (μgg^{-1})					
Sed	31(21)	138(49)	131(54)	336(119)	80(22)
Ult	84(16)	60(26)	284(108)	401(120)	276(34)
Ex. Mn (μgg^{-1})					
Sed	2(1)	5(2)	4(1)	20(16)	18(6)
Ult	18(11)	14(6)	32(13)	33(13)	5(14)
Gravimetric soil water contents (%)					
Sed	27.4(1.2)	56.2(5.9)	70.1(5.7)	66.3(6.5)	47.7(1.8)
Ult	22.4(.5)	38.5(.5)	42.9(1.1)	48.7(3.3)	30.2(1.2)

Table 2. In-situ net soil N transformation rates on an oven-dry weight basis per 10 days, and fractions of soil total-N transformed to inorganic N. The fractions are expressed as mineralized N per g total-N (mg/g/10d). Values are means (±sd). 'Sed' denotes sedimentary rock sites, and 'Ult' denotes ultrabasic rock sites. AOV, one-way analysis of variance; * $P<0.05$, ** $P<0.01$, *** $P<0.001$.

Alt (m)	800	1400	2100	2700	3100
Nitrification ($\mu g g^{-1} 10d^{-1}$)					
Sed	22.2(3.5)	12.0(6.9)	0.1(.1)	7.7(1.8)	6.4(1.8)
Ult	10.2(4.6)	0.8(.5)	1.9(3.1)	2.3(1.6)	0.2(.2)
AOV	*	*		*	**
Mineralization ($\mu g g^{-1} 10d^{-1}$)					
Sed	19.9(3.3)	35.3(16.1)	-1.6(12.6)	-1.3(7.2)	5.5(1.2)
Ult	8.5(2.4)	6.0(1.6)	1.6(1.8)	0.4(1.2)	-2.2(.3)
AOV	**	*			***
Fraction of total-N mineralized ($mg g^{-1} 10d^{-1}$)					
Sed	9.7(1.7)	5.4(1.1)	-0.1(1.5)	-0.04(.8)	0.9(.2)
Ult	4.1(.9)	1.8(.5)	0.6(.6)	0.1(.3)	-0.9(.2)
AOV	**	**			***

Table 3. Common-site net soil N transformation rates on an oven-dry weight basis per 10 days. Soils were collected from each site, and incubated under the same condition at 20.5 (±0.4)°C in the dark. Values are means (±sd). Values which share the same letter do not differ from each other at $P=0.05$ (Tukey's HSD). 'Sed' denotes sedimentary rock sites, and 'Ult' denotes ultrabasic rock sites.

Alt (m)	800	1400	2100	2700	3100
Nitrification ($\mu g g^{-1} 10d^{-1}$)					
Sed	19.5(3.3)a	15.1(9.2)ab	0.4(.2)b	14.6(9.9)ab	9.6(2.3)ab
Ult	9.8(4.5)a	0.8(.6)b	3.4(4.7)ab	2.8(2.6)ab	0.1(.1)b
Mineralization ($\mu g g^{-1} 10d^{-1}$)					
Sed	17.5(3.0)a	33.4(11.0)a	5.6(17.5)a	23.8(25.5)a	9.5(2.4)a
Ult	7.5(2.6)a	6.7(2.7)ab	0.003(1.25)cd	1.5(2.0)bc	-4.1(.6)d

Table 4. Effects of P fertilization on net soil N transformation rate, which are determined by the amount of N produced under the P treatment minus that of the controls (the common-site treatment). Values are means (±sd). Significant effects are denoted by * ($P<0.05$) and **($P<0.01$) (paired T test). 'Sed' denotes sedimentary rock sites, and 'Ult' denotes ultrabasic rock sites.

Alt (m)	800	1400	2100	2700	3100
Nitrification ($\mu g g^{-1} 10 d^{-1}$)					
Sed	-1.8(.8)*	-2.8(1.7)	-0.4(.2)*	-0.5(.8)	-1.7(1.1)
Ult	-0.7(1.6)	-0.1(.08)	1.2(2.5)	-0.6(.1)**	-0.1(.1)
Mineralization ($\mu g g^{-1} 10 d^{-1}$)					
Sed	-2.5(.8)*	-3.1(3.9)	-6.4(3.7)	-3.7(7.6)	-2.3(1.4)
Ult	-2.9(1.5)*	-3.4(2.2)	-4.7(1.0)**	-2.8(.7)**	1.2(.6)*

SECTION 2 RESPONSES OF FOREST ECOSYSTEM TO GLOBAL WARMING WITH PARTICULAR REFERENCE TO LEAF LONGEVITY AND LEAF HABIT OF TREES

1. Introduction

To clarify the effect of climatic change in particular global warming on forest is the purpose of this study. Temperature affects plant indirectly through the changes in seasonality as well as affects directly upon plant's physiological activities. As for the effects on leaf longevity of plants, temperature affects leaf longevity through the changes in photosynthetic rates and affects leaf-habit or deciduousness and evergreenness through the changes in the length of favorable period for photosynthesis (see Fig. 1). By using the model for leaf-longevity, we analysed the effect of global change on the length of leaf longevity. Then we analysed the effect of the length of favorable period on leaf-habit by using the synthetic model. Then we applied the models to Monsoon Asia and estimated the distribution of leaf longevity and leaf habit through altitudes and latitudes. In order to verify the prepositions supposed by the models and to examine the effect of climate on leaf habit and leaf longevity by excluding the effect of seasonality, a research on leaf longevity was carried out on Mt. Kinabalu.

2. Results and discussion

Almost all of trees on Mt. Kinabalu showed evergreen leaf-habit. However, leaf longevities were various (Fig. 2). Many trees have longer leaf longevity than 1 year, some of them have those longer than 10 years. But some trees have shorter leaf longevity than 1 year. Mixing of longer and shorter leaf longevities were found throughout altitudes. Schima walichii, a tree species which has wider altitudinal distribution exhibited longer leaf longevity with higher altitudes. These trends found in this study are consistent with predictions from the model.

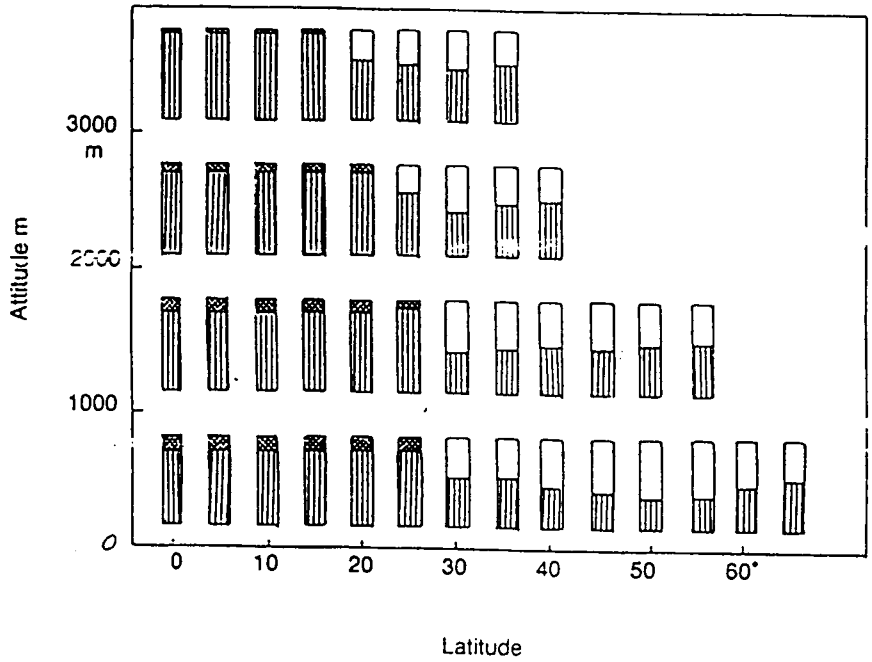

Fig. 1. Proportions of evergreen to deciduous species, which are predicted from the model used in this study, in a matrix of latitudes and altitudes. Open areas for deciduous species, areas with vertical lines for evergreen species. Dotted areas indicate evergreen species with leaf longevity <1 yr.

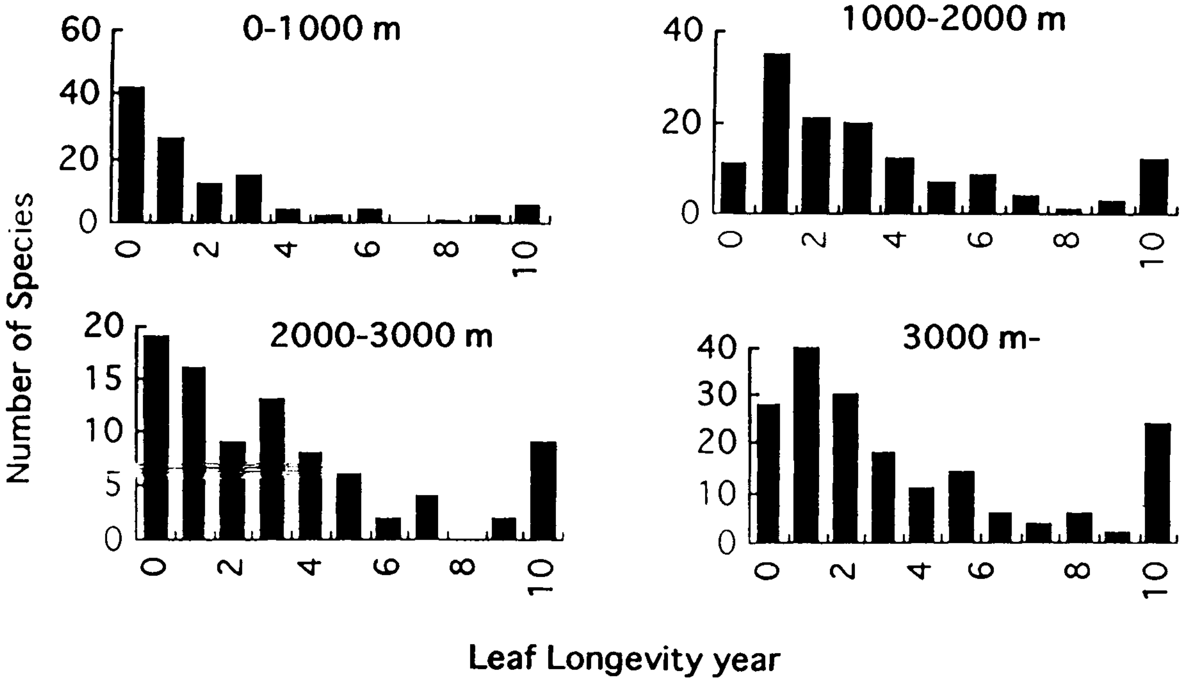

Fig. 2. Frequency distribution of leaf longevity on Mount Kinabalu in four altitudinal vegetatio zones.