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Effect of climate on vegetation-soil system after volcanic ash deposition 7300 years ago on Yakushima Island

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Today's vegetation on Yakushima Island varies across elevations. Yakushima Island is covered with the Akahoya volcanic ash being derived from the Kikai Caldera about 7300 years ago. The eruption was so destructive that today's vegetation was established through primary succession after the volcanic eruption. The five independent state factors, which are climate, topography, organism, parent material and time, must have intricately affected the formation of the current soil-vegetation system. Among five factors, Climate including precipitation and temperature must have strongly affected the formation of today's vegetation. The purpose of this study is to clarify how climate has influenced the vertical distribution of the vegetation during 7300 years by investigating the relationships between soil mineral nutrients and nutrient-use efficiencies of the vegetation.

In this study, seven permanent study plots were set up along the elevation gradient. Soil samples (0-10, 10-20 cm depth) were randomly collected from each forest. We determined phosphorus (P) fraction in the soils following the method of Tiessen & Moir (1993). Inorganic nitrogen (N) and exchangeable cations were determined by using the extract with 1.5N KCl. P and N in collected fresh litter were determined by using Kjeldahl digests with concentrated H_2SO_4 and H_2O_2. We calculated mean values of soil elements in each forest and examined the relationships with temperature and precipitation. Temperature and precipitation data were cited from the publicized national numerical average data. Both data do not correlate with each other.

Soil total P (Pt) and inorganic N had a significant positive correlation with temperature but not with precipitation. Occluded-P (Occl-P) had a strongest negative correlation with temperature among P fractions. On the other hand, exchangeable cation had a stronger negative correlation with precipitation than with temperature. Pt and inorganic N had a negative correlation with each nutrient-use efficiency.

P is an essential element whose primary source is the weathering of minerals in parent materials. Considering that the pedogenesis on Yakushima Island is merely 7300 years, P in current topsoil must be derived primarily from the Akahoya volcanic ash. According to Walker & Syers (1976), Pt and acid extractable Ca-P in soils decrease along a pedogenesis chronosequence. In addition, Occl-P being unavailable to plants, increases with the progress of weathering. However, our results indicate that Occl-P is higher at lower elevations and that Pt is lower at higher altitudes where the intensity of weathering is low because of low temperature. Moreover, Ca-P, which is a primary mineral P in parent materials, decreases with increasing elevation. These results are not in accordance with the model of Walker & Syers (1976). We suggest that temperature and precipitation have intricately affected the weathering and leaching of nutrients, and influenced the formation of P fractions.

At higher elevation sites, annual rainfall exceeds annual evapotranspiration. As soil organic matter is decomposed, soils will be reduced by respiration of microbes and soil pH will be lower. Consequently, at higher elevation, acid extractable Ca-P and aluminum (Al) and iron (Fe) are dissolved and then P bound to Al and Fe are leached from topsoil. At lower elevation sites, Occl-P is formed but Pt is also kept and soil inorganic P as a plant available form is higher. Soil inorganic N is also higher at lower elevations probably due to the direct effects of temperature as well as the indirect effects via P availability; the two effects are, however, inseparable in this study.

In conclusion, the availability of P and N varied across elevations primarily due to temperature, which in turn determined P- and N-use efficiencies of the forests. Today's vegetation is, thus, formed via the effects of soils as a function of temperature in addition to the direct effects of temperature on plants.

Keywords: Phosphorus, Volcanic Ash, Nutrient-use efficiency, Climate, Pedogenesis