Soil carbon stocks estimation with reference to the degree of volcanic ash additions in Japanese forest soils

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Abstract
The objective of this study is to clarify the influence of volcanic ash addition on the soil carbon stocks and their accumulation process in Japanese forest soils. Volcanic ash additions to the soil were estimated based on the acid ammonium oxalate extractable aluminium (Alox) content, lithic fragment abundance and their vertical distribution patterns. The carbon in soil samples is controlled by Al-humus complex formation which is determined by the free Al generated from accumulated volcanic ash. The stratigraphical relationship of volcanic ash accumulation horizons affected the vertical distribution of carbon. In addition, successive accumulation of volcanic ash on the soil surface leads to development of the soil surface horizon and to increased soil carbon stock. These influences to soil carbon accumulation due to the degree of volcanic ash addition to soil resulted in variable soil carbon stocks among soil types reflecting the degree of volcanic ash addition. Our results suggest that volcanic ash addition controls the soil carbon stock of these Japanese forest soils.

Key Words
Volcanic ash, soil carbon stock, forest soil, Al-humus complex formation, free Al.

Introduction
Information on soil derived from volcanic ash will be important for evaluating and predicting the soil carbon stock. However, the method of estimation of volcanic ash additions is not established for the Japanese forest soils. The objectives of this study were to clarify the influence of volcanic ash addition on the soils and to classify these soils in detail based on their andic soil properties and to clarify the influence of volcanic ash addition on soil carbon accumulation in forest soils of Japan.

Methods
Soils
86 sola of Japanese forest soil such as Brown Forest soils (BFS), Black soils (BLS), Red soils (R) and Immature soils (Im) were used. These soils could be classified into Andosols, Umbrisols and Cambisols according to WRB 2006. Studied soils experience 7.5-16.2 ºC of mean annual air temperature, 1385-3641 mm of annual precipitation, and 37-1300 m of altitude. Various rocks, i.e., igneous, sedimentary, metamorphic, and volcaniclastic materials underlie these soils. These soils are under plantation forest of Japanese cedar or Japanese cypress and secondary forest of fagus, quercus and other broad leaved trees.

Chemical analysis
Total soil organic carbon was analyzed using the dry combustion method (MT-600 CN Corder Yanaco, Kyoto, Japan). Dry bulk density of the fine earth (< 2 mm) was measured by the core method (Soil Survey Laboratory 1996). The volume of lithic fragments was estimated from the lithic fragment abundances in the field profile description (Food and Agriculture Organization 1990). Acid oxalate extractable Al (Alox) and pyrophosphate extractable Al (Alpy) were determined using ISRIC methods (Reeuwijk 1993).

Soil carbon stock analysis
The soil carbon stocks were calculated for 0-30 cm depth, 0-100 cm depth and effective soil depth using the total soil organic carbon content, dry bulk density and abundance of lithic fragments.

Results
Volcanic ash additions to the soil were estimate based on the Alox content and lithic fragment abundance and their vertical distribution patterns. Therefore, BFS were classified in order of increasing volcanic ash additions to the soil parent material: H-Alox-NGv, H-Alox-Gv, M-Alox, and L-Alox. H-Alox-NGv BFS was characterized by an increase in the Alox content to ≥ 20 g/kg from the surface to subsurface horizons and a

near or complete absence of lithic fragment throughout the profile. H-Alox-Gv BFS was also characterized by Alox of ≥ 20 g/kg in the subsurface horizon but many lithic fragments were present in the surface and/or subsurface horizons. In the M-Alox BFS type, the maximum Alox content was > 4 g/kg but < 20 g/kg. In the L-Alox BFS type, the Alox content in the surface and subsurface horizons was < 4 g/kg.

Correlation with carbon amount, Alox amount and Alpy amount in the soil samples suggests that carbon amounts are controlled by Al-humus complex formation which is due to the free Al generated from accumulated volcanic ash (Figure 1). Comparison between vertical distribution patterns of carbon amount, Alox amount and Alpy amount show that stratigraphical relationships of volcanic ash accumulated horizons and carbon amounts. In addition, successive accumulation of volcanic ash on the soil surface which is shown by the vertical distribution pattern of Alox, leads to development of the soil surface horizon and increases the soil carbon stock. The soil carbon stocks were larger in the order BLS > H-Alox-NGv BFS, H-Alox-Gv BFS > M-Alox BFS > L-Alox BFS, R and Im (Table 1). These influences on the soil carbon accumulation process by the degree of volcanic ash additions to soil have resulted in various the soil carbon stocks among the soil types reflecting the degree of volcanic ash addition.

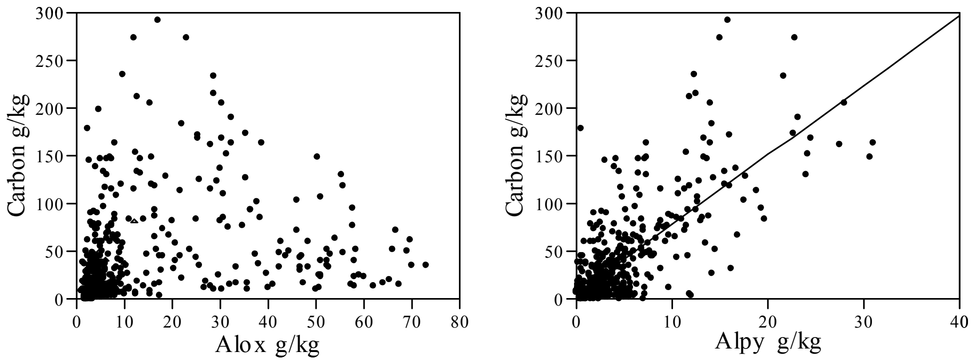

Figure 1. Relationships between carbon contents and Alox, Alpy contents in the soil samples.

Table 1. Soil carbon stocks in each soil type according to the advanced classification.

Soil type (number of sola)	Volcanic ash addition	0-30cm	0-100cm	Effective soil depth
			(kg/m^2)	(cm)
BLS (6)	Accumulated	14.8	35.6	41.8
H-Alox-NGv BFS (6)	Accumulated	12.2	23.8	33.2
H-Alox-Gv BFS (7)	Highly mixed	10.3	18.5	22.3
M-Alox BFS (45)	Lowly mixed	7.1	10.5	11.1
L-Alox BFS (17)	Absent	4.5	6.6	6.2
R (3)	Absent	5.1	6.7	7.0
Im (2)	Absent	2.9	3.4	3.1

Conclusion

Degree of volcanic ash additions to the soil could be estimated using the BFS classification and based on Alox content, lithic fragment abundance and their vertical distribution patterns, as proposed in this work, and can provide insight into different pedogenetic processes. We found that the volcanic ash additions control the soil carbon stocks of Japanese forest soils.

References

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