Soil erosion characteristics under rainfall simulator conditions of the Jeju soil in Korea

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Abstract
In order to investigate the effect of soil physical properties, runoff and infiltration water on soil erosion, soil samples were collected from 5 sites of dark brown soil(DBS), 6 sites of very dark brown volcanic ash soil(VDBAS), and 8 sites of black volcanic ash soil(BVAS) in Jeju. The relations between soil erosion and some physical characteristics of the soil were tested. The relationship between soil erosion and runoff was positively correlated, but infiltration water and saturated hydraulic conductivity were negatively correlated with soil erosion in all soils. In DBS, the soil erosion was negatively correlated with clay, clay/silt, clay+very fine sand, clay/(silt+very fine sand) and clay+fine sand(0.02-0.2 mm), but positively correlated with silt/clay. In BVAS, the soil erosion was negatively correlated with silt/clay and positively correlated with clay+fine sand (0.02-0.2 mm). The relationship between soil erosion and water stable aggregate was observed only in the DBS and VDBAS. Soil erosion in DBS was positively correlated with water stable aggregate (0.25-0.5 mm, 0.1-0.25 mm + 0.25-0.5 mm, 0.1-0.25 mm + 0.25-0.5 mm + 0.5-1.0 mm), but the water stable aggregates (0.5-1.0 mm + 1.0-2.0 mm + >2.0 mm and 1.0-2.0 mm + >2.0 mm) were prone to decrease soil erosion without statistical significancy. Soil erosion in VDBAS was positively correlated with water stable aggregate (0.1-0.25 mm, 0.25-0.5 mm and 0.1-0.25 mm + 0.25-0.5 mm), but negatively correlated with water stable aggregate (0.5-1.0 mm + 1.0-2.0 mm + >2.0 mm and 1.0-2.0 mm + >2.0 mm). In DBS and VDBAS, soil erosion decreased with increasing of soil organic matter content, but in BVAS, there was no relationship between soil erosion and organic matter content.

Key Words
Soil erosion, volcanic ash soil, rainfall simulator, soil physical properties.

Introduction
Soil of the Jeju in Korea is affected by severe soil erosion. Most areas are under conventional tillage, by which the upper soil layer is turned after harvest before sowing, this results in an uncovered soil surface during July, August and September. These months are characterized by the highest rainfall amounts. Soil erosion caused by water is primarily due to particle detachment and transport by rainfall and runoff. The physical soil properties and interactions that affect K values are many and varied. The objective of this study was to relate erodibility factors and physical properties of volcanic ash soil from the Jeju Island in Korea under simulated rainfall. Another goal was to determine the erodibility factors for volcanic ash soil from Jeju Island.

Methods
Soil samples were collected at field moisture condition. After air-drying, the soil was passed through a 2mm sieve and then packed in soil pan (width : 26×30cm, depth : 10cm). The soil then was saturation with distilled water. After saturation, the pan was set at 10% slope and allowed to drain for about 24 hour. Rain was applied for 30 minute at 150mm/h using a simulated rainfall (Diameter of drops 5.9mm, Mass of drops 0.1g, Number of capillary tubes 49) at a height of 0.4m. Infiltrating water was collected from the bottom, while runoff plus sediments were sampled at the upper of the pan using a tall beaker. The organic matter of soil was estimated using 0.4N $K_2Cr_2O_7$ as oxidant and 0.2N $Fe(NH_4)_2(SO_4)_2$as titrant. Particle size analysis was determined on the < 2 mm fraction by the pipette method. Water stable aggregate analysis was determined on the 2-4mm fraction by a Yoder-type aggregate distribution analyzer.
Soil properties used in the study are summarized in Table 1 and 2. Table 1 shows the particle size for the different soils. The average contents of sand, silt and clay were 13.6%, 67.1% and 19.4% in DBS, 12.3%, 66.8% and 20.9% in DBVAS, and 10.2%, 71.0% and 18.8% in BVAS, respectively.

Table 1. Particle size of soils used in the experiment.

Soil colors	Soil series	U. S. Department of Agriculture								International Soc. of Soil Sci.			
		Sand						Silt	Clay	Coarse sand	Fine sand	Silt	Clay
		(------%------)											
		2.0-1.0	1.0-0.5	0.5-0.25	0.25-0.1	0.1-0.05	Total	0.05-0.002	<0.002	(2.0-0.2)	(0.2-0.02)	(0.02-0.002)	<0.002
		(------mm------)											
Dark brown soil	Gyorye	3.9	6.0	6.4	6.4	3.4	26	52.0	22.1	17.2	30.9	29.9	22.1
	Gueom	0.4	0.9	1.6	2.6	1.4	6.9	78.9	14.3	3.4	17.7	64.6	14.3
	Donggwi	1.8	4.0	4.1	4.9	2.4	17.3	70.6	12.2	10.8	18.6	58.4	12.2
	Donghong	0.5	1.4	1.9	2.7	3.0	9.4	55.0	35.6	4.1	40.9	19.4	35.6
	Jocheon	0.2	1.1	2.0	3.8	1.2	8.3	79.2	12.6	3.9	16.9	66.6	12.6
	Mean	1.4	2.7	3.2	4.1	2.3	13.6	67.1	19.4	7.9	25.0	47.8	19.4
Very dark brown volcanic ash soil	Gujwa	0.5	1.8	2.9	4.0	2.8	12.0	62.6	25.4	5.8	31.6	37.2	25.4
	Ora	0.4	1.2	2.2	3.2	1.9	8.8	73.1	18.0	4.4	22.5	55.1	18.0
	Jeju	0.6	1.8	2.5	3.2	2.0	9.9	73.6	16.5	5.3	21.1	57.0	16.5
	Jungmun	0.2	1.0	1.8	3.3	4.5	10.8	68.8	20.4	3.5	27.7	48.5	20.4
	Jungeom	0.1	0.3	0.4	0.7	1.4	2.9	72.4	24.7	1.0	26.7	47.6	24.7
	Hallim	2.4	4.9	7.7	11	3.2	29.2	50.3	20.5	16.4	33.3	29.8	20.5
	Mean	0.7	1.8	2.9	4.2	2.6	12.3	66.8	20.9	6.1	27.1	45.9	20.9
Black volcanic ash soil	Gimnyeong	3.5	3.8	2.5	2.6	3.0	15.4	61.2	23.4	10.2	28.7	37.7	23.4
	Namwon	0.4	0.6	0.9	1.5	2.2	5.5	74.9	19.6	2.0	23.1	55.3	19.6
	Songdang	1.0	2.2	2.9	5.8	3.3	15.3	64.7	20.1	6.8	28.5	44.6	20.1
	Sineom	0.2	0.4	0.4	0.6	1.7	3.4	76.6	20.0	1.1	22.3	56.6	20.0
	Wimi	0.2	0.5	0.5	2.0	2.6	5.8	78.6	15.6	1.4	20.0	63.0	15.6
	Pyeongdae	0.3	1.0	1.1	1.0	3.2	6.7	76.7	16.6	2.6	20.7	60.1	16.6
	Hangyeong	0.2	0.7	1.1	2	2.2	6.2	73.3	20.6	2.3	24.5	52.8	20.6
	Haengwon	4.1	4.9	4.8	6.5	3.2	23.5	62.2	14.3	14.6	23.2	47.9	14.3
	Mean	1.2	1.8	1.8	2.8	2.7	10.2	71.0	18.8	5.1	23.9	52.3	18.8

Organic matter content and saturated hydraulic conductivity were remarkably high in BVAS, and very low in DBS. DBS had higher bulk densities, VDBVS medium ones, and BVAS lower ones. The average abundance of water stable aggregates was 68.6% in DBS, 81.8% in VDBVS, and 81.4% in BVAS, respectively(Table 2).

Table 2. Physical characteristics of soil used in the experiment.

Soil colors	Soil series	Water stable aggregate (%)						Organic matter (g/kg)	Bulk density (g/cm^3)	Saturated hydraulic conductivity (cm /h)
		0.1-0.25 mm	0.25- 0.5 mm	0.5 -1.0 mm	1.0 -2.0 mm	>2.0 mm	Total			
Dark brown soil	Gyorye	8.8	9.9	12.0	16.3	6.8	53.9	23.3	1.20	0.85
	Gueom	14.7	21.7	20.9	19.5	3.1	79.9	21.9	1.45	0.08
	Donggwi	17.3	23.1	14.6	7.7	2.1	64.9	21.6	1.41	0.20
	Donghong	4.4	9.7	19.2	29.3	28.3	90.9	51.3	1.12	1.06
	Jocheon	23.4	16.6	6.1	6.7	0.5	53.3	20.8	1.50	0.11
	Mean	13.7	16.2	14.6	15.9	8.2	68.6	27.8	1.34	0.46
Very dark brown volcanic ash soil	Gujwa	0.3	0.3	0.4	4.9	70.7	76.5	200.0	0.70	2.30
	Ora	3.6	8.2	15.3	27.1	28.8	83.0	44.3	1.12	0.37
	Jeju	4.5	9.6	16.7	29.9	28.2	88.9	61.3	1.09	0.46
	Jungmun	8.3	10.2	10.3	14.3	23.0	66.1	72.5	0.92	0.15
	Jungeom	1.5	2.9	6.6	23.9	53.6	88.5	59.9	1.09	0.85
	Hallim	1.2	2.4	3.8	13.6	66.8	87.8	90.8	0.76	0.56
	Mean	3.2	5.6	8.9	19.0	45.2	81.8	88.1	0.95	0.78
Black volcanic ash soil	Gimnyeong	0.4	0.8	1.0	12.9	68.0	83.2	221.0	0.65	1.13
	Namwon	3.1	7.0	14.9	31.3	37.5	93.9	152.0	0.71	0.11
	Songdang	1.5	2.3	4.3	17.7	68.1	93.9	193.0	0.68	0.85
	Sineom	4.8	9.5	13.4	18.4	33.5	79.6	147.0	0.63	1.17
	Wimi	3.8	7.2	13.2	27.7	40.6	92.5	180.0	0.68	1.53
	Pyeongdae	0.1	0.1	0.2	5.8	57.0	63.3	135.0	0.59	2.27
	Hangyeong	1.9	2.9	5.3	20.5	59.8	90.4	182.0	0.56	0.22
	Haengwon	0.6	0.5	0.7	8.4	43.9	54.2	172.0	0.72	0.96
	Mean	2.0	3.8	6.6	17.8	51.1	81.4	172.8	0.65	1.03

Results

Figure 1 shows the relationship of soil erosion with runoff and infiltration water. The relationship between soil erosion and runoff was positively correlated, but infiltration water was negatively correlated with soil erosion.

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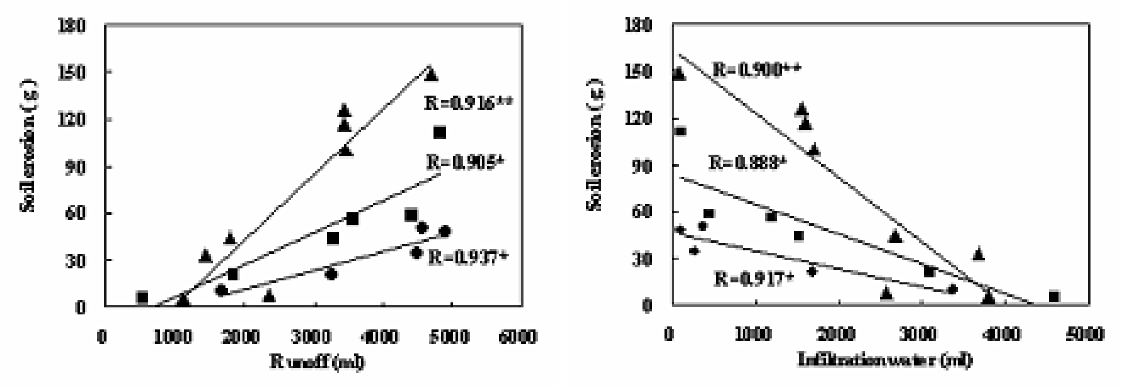

Figure 1. Relationship between soil erosion, runoff and infiltration in dark brown soil (●), very dark brown volcanic ash soil(■) and black volcanic ash soil (▲).

Table 3 shows the relationship between soil erosion and soil particle size. In DBS, the soil erosion was negatively correlated with clay, clay/silt, clay + very fine sand, clay/(silt + very fine sand) and clay + fine sand(0.02-0.2 mm), but positively correlated with silt/clay. In VDBAS, the relationship between the soil particle size and soil erosion was not significant, while in BVAS, the soil erosion was negatively correlated with silt/clay and positively correlated with clay + fine sand (0.02-0.2 mm).

Table 3. Relationship between soil erosion and particle size.

Particle size	Correlation coefficient		
	Dark brown soil (n=5)	Very dark brown volcanic ash soil (n=6)	Black volcanic ash soil (n=8)
Clay(<0.002 mm)	-0.901*	-0.599	0.642
Silt(0.002-0.05 mm)	0.801	0.202	-0.378
Very fine sand(0.05-0.1 mm)	-0.637	0.633	-0.063
Clay/Silt	-0.921*	-0.526	0.635
Clay+Very fine sand	-0.901*	-0.379	0.649
Clay/(Silt+Very fine sand)	-0.920*	-0.579	0.643
Silt/Clay	0.890*	0.460	-0.727*
Silt£+Very fine sand+Fine sand	0.848	0.452	-0.435
Clay+Fine sand(0.02-0.2 mm)	-0.913*	-0.462	0.723*

*Significant at P<0.05.

Table 4 shows the relationship between soil erosion and water stable aggregate. Soil erosion in DBS was positively correlated with water stable aggregate (0.25-0.5 mm, 0.1-0.25 mm + 0.25-0.5 mm, 0.1-0.25 mm + 0.25-0.5 mm + 0.5-1.0 mm), but the water stable aggregates (0.5-1.0 mm + 1.0-2.0 mm + >2.0 mm and 1.0-2.0 mm + >2.0 mm) were prone to decrease soil erosion without statistical significancy. Soil erosion in VDBAS was positively correlated with water stable aggregate (0.1-0.25 mm, 0.25-0.5 mm and 0.1-0.25 mm + 0.25-0.5 mm), but negatively correlated with water stable aggregate (0.5-1.0 mm + 1.0-2.0 mm + >2.0 mm and 1.0-2.0 mm + >2.0 mm). However, in BVAS soil erosion was not correlated with water stable aggregate.

Table 4. Relationship between soil erosion and water stable aggregate.

Water stable aggregate	Correlation coefficient		
	Dark brown soil (n=5)	Very dark brown Volcanic ash soil (n=6)	Black volcanic ash soil (n=8)
0.1-0.25 mm	0.719	0.954**	0.084
0.25-0.5 mm	0.976**	0.849*	0.063
(0.1-0.25 mm)+(0.25-0.5 mm)	0.917*	0.914*	0.071
(0.1-0.25 mm)+(0.25-0.5 mm)+(0.5-1.0 mm)	0.949*	0.782	0.005
(0.5-1.0 mm)+(1.0-2.0 mm)+(>2.0 mm)	-0.631	-0.843*	0.666
(1.0-2.0 mm)+(>2.0 mm)	-0.762	-0.893*	0.650
(0.1-0.25 mm)+(0.25-0.5 mm)+(0.5-1.0mm) + (1.0-2.0 mm)+(>2.0 mm)	-0.227	-0.550	0.560

**Significant at P<0.01, *Significant at P<0.05.

Table 5 shows the relationship between soil erosion and bulk density, soil organic matter and saturated hydraulic conductivity. The bulk density did not significantly affect soil erosion, but the relationship between soil erosion and bulk density in DBS was considerably higher in comparison to VDBAS and BVAS. In DBS and VDBAS, soil erosion decreased with increasing soil organic matter content, but in BVAS, there was no relationship between soil erosion and organic matter content. Soil erosion was negatively correlated with saturated hydraulic conductivity for all soils.

Table 5. Relationship between soil erosion and physical characteristics.

Physical characteristics	Correlation coefficient		
	Dark brown soil (n=5)	Very dark brown volcanic ash soil (n=6)	Black volcanic ash soil (n=8)
Bulk density	0.860	0.253	-0.374
Organic matter	-0.762	-0.664	0.390
Saturated hydraulic conductivity	-0.919*	-0.787	-0.841**

**Significant at P<0.01, *Significant at P<0.05.

Conclusion
The soil erodibility factor (K) represents the effect of soil properties and soil profile characteristics on soil loss. The physical, chemical, and mineralogical soil properties and their interactions that affect K values are many and varied. Therefore, this study emphasizes some factors affecting soil erodibility of the Jeju soil in Korea. For Dark brown soil and Very dark brown soil, soil erodibility factor(K-factor) were runoff water, infiltration water, soil particle size, water stable aggregate, soil organic matter and saturated hydraulic conductivity, and for Black volcanic ash soil were runoff water, infiltration water, soil particle size and saturated hydraulic conductivity.

References

Fontes JC, Pereira LS, Smith RE (2004) Runoff and erosion in volcanic soila of Azores : simulation with OPUS. *Catena* **56**, 199-212.

Miller WP (1987) Infiltration and soil loss of three gypsum-amended ultisols under simulated rainfall. *Soil Sci. Soc. Am. J.* **51**, 1314-1320.

Poulenard J, Podwojewski P, Janeau JL, Collinet J (2001) Runoff and soil erosion under rainfall simulation of andisols from the Ecuadorian Paramo : effect of tillage and burning. *Catena* **45**, 185-207.

Reichert JM, Norton LD, Huang CH (1994) Sealing, amendment, and rain intensity effects on erosion of high-clay soils. *Soil Sci. Soc. Am. J.* **58**, 1199-1205.

Truman CC, Bradford JM, Ferris JE (1990) Antecendent water content and rainfall energy influence on soil aggregate breakdown. *Soil Sci. Soc. Am. J.* **54**, 1385-1392.