Water Retention Characteristics of Soil-Organic Amendment and its Erodibility under Simulated Rainfall

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1. Introduction

A soil with low organic matter content (OMC) is susceptible to soil erosion. Organic matter content influences soil erodibility (Wischmeier and Mannering, 1969). Adding organic matter into a soil or soil-organic amendment (SOA) is one of the sustainable measures to mitigate and control soil erosion in agricultural farmland. As SOA is to improve physical, chemical, and biological properties of a soil, soil erosion can be retarded and result in increase of soil fertility contributes to continual production of organic matter (i.e. vegetation) in ecosystem.

Organic wastes such as sewage sludge, animal manure, crop residual, compost, biosolids, biochar, wood chips, and organic byproduct can be good recycled materials. Amending these materials into soil can reduce wastes, cost, and chemical fertilizer in agriculture and improve soil properties. For example, soil aeration, water infiltration, and water and nutrient holding capacity can be improved.

As climate change is expected to vary precipitation patterns and affects soil erosion characteristic. Therefore, study on influences of organic matters on soil properties such as soil water retention and resistance against rainfall is required. In addition, nutrient loss through runoff from soil-organic amendment will also be needed.

2. Materials and Methods

2.1 Materials

Red soil (Kunigami maaji) from Okinawa was used to mix with compost and rice husk biochar. The soil and compost were air-dried and passed 2.0 mm sieve. Specimens were hand compacted to achieve a bulk density of 1.4 g/cm^3. For water retention tests, compost was mixed with red soil (RS) at rate of 0.5, 1.0, 1.5, and 2.0 kg/m^2 (indicated by RSC0.5, RSC1.0, RSC1.5, and RSC2.0, respectively) and red soil were mixed with compost of 1.0 kg/m^2 and biochar (1, 3, and 5%) (indicated by RSCB1, RSCB3, and RSCB5, respectively). For rainfall experiments, RS, RSC1.0, and RSCB5 were employed and compacted in a soil box of 50 cm (length) x 25 cm (width) and 5 cm (thickness).

2.2 Methods

2.2.1 Determination of Water Retention Curves

Water retention curve (WRC) of a soil or a material represents amount of water holing in its pores under stress conditions such matric and osmotic suction. Drawback of determining WRC is due to lengthy time, high cost, and available equipment. In this study, compact high speed refrigerated centrifuge (model 6500 from Kubota corp.) was used. Suction conversion in centrifuge device was carried out by changing the test speed (i.e., angular velocity, ω) can be represented by proposed equation from Garner (1937) (1). Measured data of WRC were then fitted with equation from van Genuchten (1980) (2) to predict water characteristic beyond measured values.

$$\psi = \frac{\rho\omega^2}{2}\left(r^2{}_2 - r^2{}_1\right) \qquad (1)$$

ψ is suction (kPa), r_1 is radial distance to the free water surface (cm), r_2 is radial distance to the midpoint of the soil specimen (cm), ω is angular velocity (rad/s), ρ is density of the pore fluid (g/cm^3)

$$\theta = \theta_r + (\theta_s - \theta_r)\left[1 + (\alpha h)^n\right]^{-m} \qquad (2)$$

θ is volumetric water content, h is water pressure (kPa), θ_s and θ_r are the saturated and the residual volumetric water contents, α, n, and m are empirical parameters.

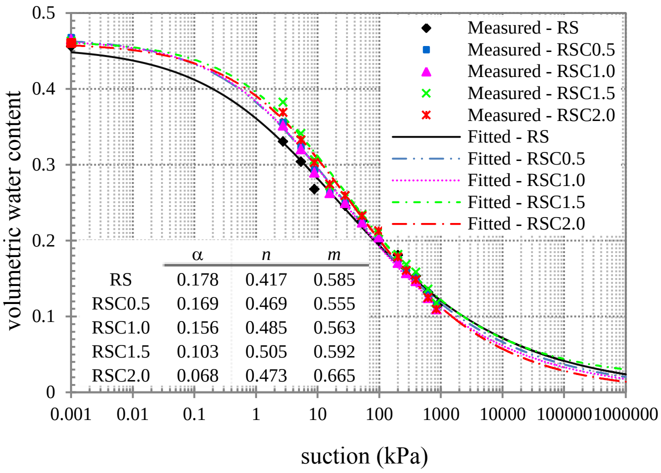

Figure 1. water retention curves of red soil and compost

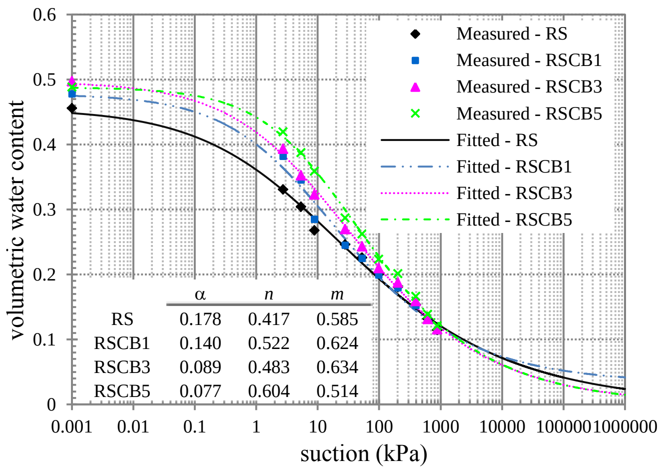

Figure 2. water retention curves of red soil, compost, and biochar

2.2.2 Rainfall experiment and soil loss determination

Rainfall experiment consists of artificial rainfall simulator, soil box, and support structure. Rainfall simulator is a drip type using 170 hypodermic needles (id = 1.0 mm spacing at 30 mm). The simulator was connected to tap water and water dropped at 1.5m in height to soil box which tilted at 3° and its perforated base allows drainage. Samples were soaked for 48 hours before 60-minute rainfall was applied and runoff was collected at 2-minute interval. The end of previous experiment was then set as initial condition for the next rainfall experiments. Pet bottles were used as sample collector. Collected runoff was poured to recycled soft drink cans for measuring electrical conductivity (EC) using conductivity meter from Horiba ltd. Samples were placed in a 105^{oC} dried oven for measuring dried mass of soil loss.

3. Results and Discussion

3.1 Effect of organic matter contents on water retention

Rawls et. al. (2003) reviewed literature reports on relationship between soil water retention and OMC was contradictory and concluded that water retention of soils with coarse texture is more sensitive to the amount of organic carbon as compared with fined-textured soils. Figure 1 and Figure 2 showed results of soil water retentions for both the measured data and fitted data including fitting parameters from equation (1). Results showed that higher OMC in Figure 2 affected vwc more than that of vwc in Figure 1. OMC in Figure 1 did not alter WRC of the RS much while OMC in Figure 2 significantly altered WRC of the RS especially at suction below permanent wilting point (suction of -1500 kPa). At higher suction beyond this point, there was not much changing in WRC for both in Figures 1 and 2.

3.2 Effect of organic matters on soil loss

Figure 3 showed soil loss results with respect to different rainfall intensities. In generally, results showed that increase in OMC from compost and biochar did not reduce soil losses. For all rainfall intensities, red soil showed minimum soil loss than all soil-organic mixtures. However, effect of organic matter on soil loss was varied. Figure 3 showed that RSC1.0 had higher soil loss than RSCB5 below intensity of 70 mm/h. when linear regression line was assumed.

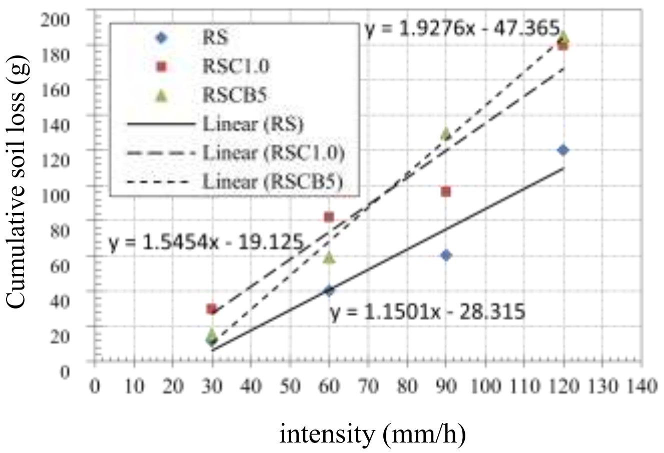

Figure 3. soil losses and intensities for 60 minutes

3.3 Infiltration and electrical conductivity

Figure 4 showed results of infiltration and electrical conductivity (EC) from collected runoff under rainfall intensity of 60 mm/h. Increase in OMC did not increase infiltration. RSC1.0 had similar infiltration to the RS, while RSCB5 reduced infiltration tremendously as compared to the RS. This might be due to influence of biochar in repelling water. It was observed that runoff from RSCB5 was increased and resulting in nutrient leaching through runoff as indirectly indicated by variation of EC in the figure. EC in collected runoff from RSCB5 was the highest while variations of EC in RSC1.0 was slightly higher than EC in RS.

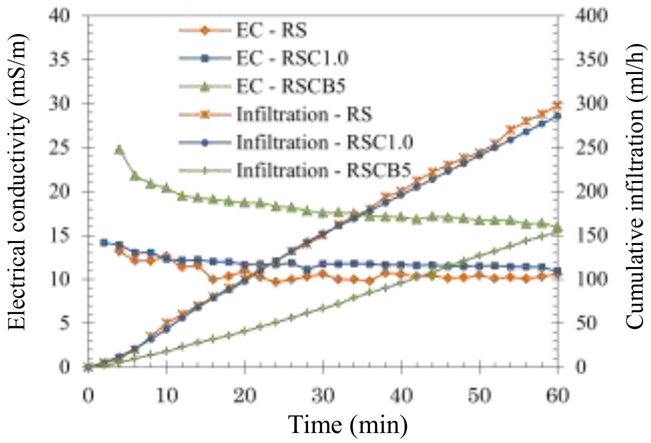

Figure 4. EC and infiltration for intensity of 60 mm/h.

4. Conclusions

Based on this preliminary study, results showed that adding organic wastes such as compost and rice hush biochar to the red soil was not effective in reducing soil loss but soil water characteristic was influenced by OMC. However, it is expected that soil properties (physical, chemical, biological) will change over time. Therefore, more study is required.

Acknowledgement

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