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The Influence of Sediment Heterogeneity on Percolation in Sand Dune

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Abstract: In this research, we aimed to clarify the phenomenon of vertical soil moisture movement in dune. Moreover, the dominant factor of soil moisture movement was checked. Research area was Tottori sand dune, Japan. We set an observation point for soil moisture profile and an artificial outcrop for the sedimentary structures and the detailed soil moisture profile. As the observation result, the soil moisture inside the dune was heterogeneous and had a layered structure. However, this observation point consisted of almost fine sand from the grain mechanical analysis. There was no remarkable difference of sediment. Then we checked the sedimentary structures to the last detail by artificial outcrop. Under surface, there was a compound cross lamina structure. Additionally, the soil moistures on each cross lamina borders were constantly higher than other depths. These results showed that the lamina structures controlled the soil moisture movement of sand dune.

Keywords: Lamina structure, Sediment heterogeneity, Sand dune, Soil moisture

1. Introduction

When we worked around water problems in sandy area, especially in natural dune, the percolation phenomenon was generally analyzed on the assumption that the sand sedimentary structure was homogeneous. Actually, sandy soils were formed with a uniform material compared with other soils. Therefore, the percolation analysis with a simple soil layer model was widely used for environmental and irrigation problems in sandy area. However, it was not verified enough whether the actual percolation phenomenon to the deep was the same as the homogeneous model. The objectives of this research were (1) to clarify the actual percolation feature by soil moisture observation in a natural dune, (2) to consider the factors that control percolation form.

2. Materials and Methods

The research site was located in Tottori coastal dune, Tottori, Japan (35˚32'N, 134˚12'E, Altitude 12−55 m). The mean annual precipitation was 1905 mm. Two-observation plots were set about 1 km inland from the coastline. Both points were bare soil surface and had few sand movements.

Point 1: The topological condition of point 1 was flat surrounded by windbreak forest. Soil moisture profile was measured by ADR sensors (Theta Probe-ML2, DELTA-T) during the years 2003−2007. The ADR sensor had a resistance characteristic for salinity, as Nakajima *et al.* (1998). Therefore, it was suitable for continual soil moisture measuring at seashore. The observation depth was 0.05, 0.2, 0.4, 1.0, 1.5, 2.0, 3.0, 4.0, 5.1, 6.3, 7.5, 8.7 and 9.9 m (**Fig. 1**). To excavate for each depth, we used a simple vacuum method with a dust collector, as Kawai *et al.* (2006). This evacuation method was convenient to dig deep holes in sandy soil. In addition, the groundwater level was about 10 m deep at this area from the preliminary examination (**Fig. 1**). The annual groundwater level changed about 1 m.

For other soil physicality, sand grain size and soil -moisture retentivity were measured at intervals of 50 cm.

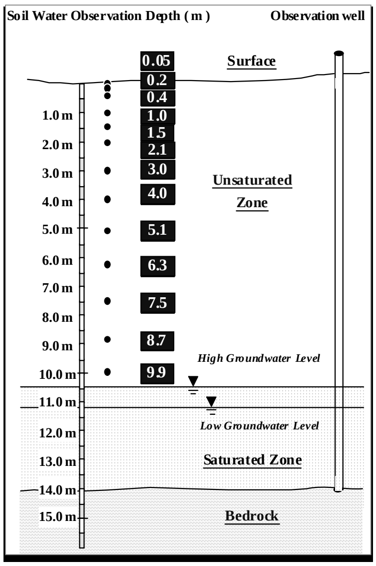

Fig. 1. Observation depth - point1.

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Point 2: The topological condition of point 2 was steep slope face to west. An artificial outcrop (2×3 m) was made in the slope and detailed sand sedimentary structures were confirmed by visual evaluation. Additionally, the soil moisture profile (2−5 cm intervals) was measured by WET sensor (DELTA-T).

3. Results and Discussion

3.1. Soil moisture (point 1)

The observation result of soil moisture was shown in **Figure 2**. This figure consisted of percolation and soil moisture graph. At the soil moisture graph, the longitudinal axis showed depth and the horizontal axis showed time. The color strength showed the volumetric water content. The soil moistures were relatively high ranging 8−15% because of much annual precipitation in Tottori area. Only the shallow depths (upper 20 cm), the soils were highly dried ranging 1−3% water content under the summer condition. The soil moistures of 2.0 and 6.0 m deep were constantly high compared with other depths. This showed that the soil moisture of vados zone was heterogeneous situation and had a layered structure. In addition,

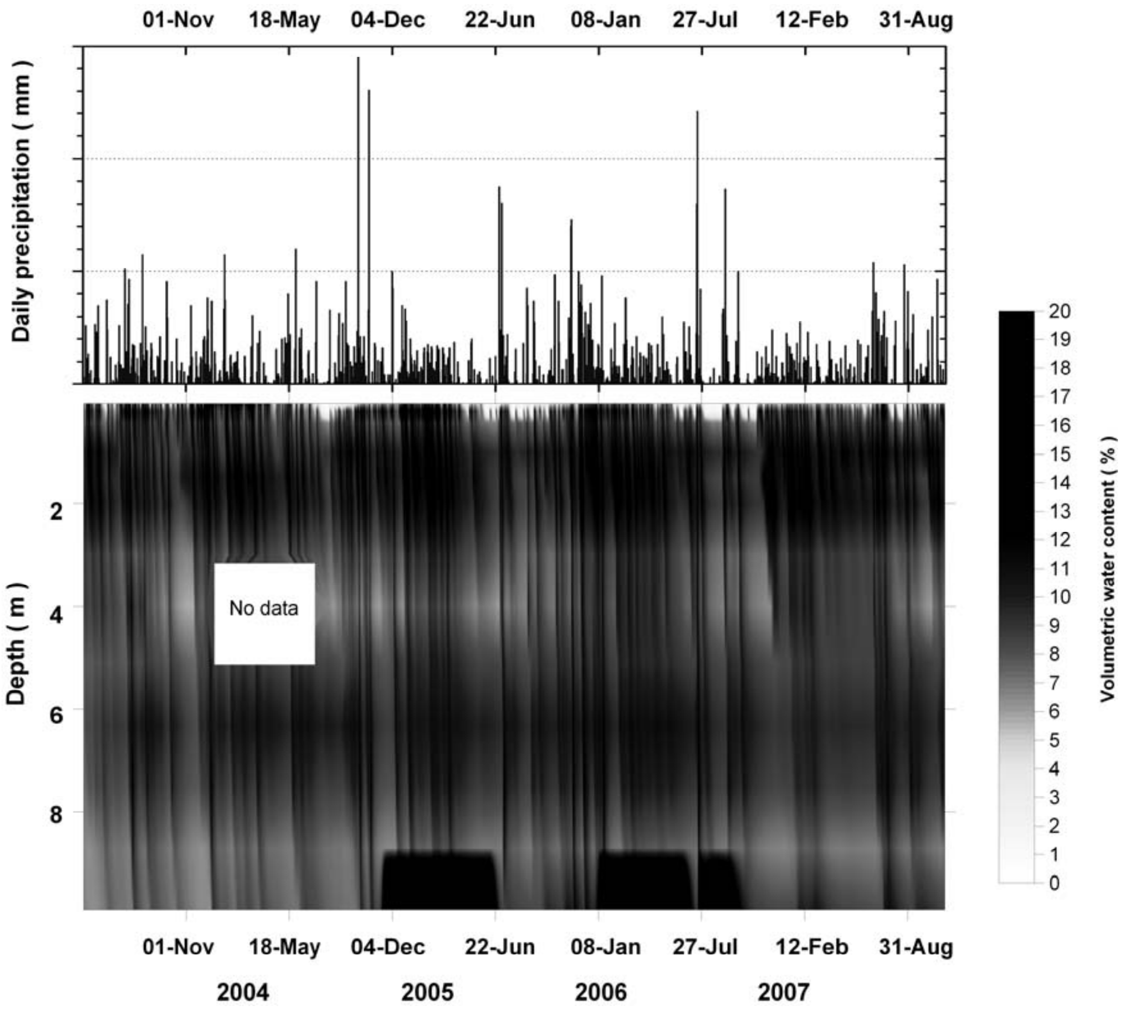


Fig. 2. Soil moisture profile and Precipitation.

the soil moisture around 9 m deep increased rapidly in the winter of 2005 and 2006 years. This was because that the groundwater level moved upwards and the sensor area became saturated zone.

Generally, heterogeneity of the soil moisture depends on the sediment structure. Then, the sand grain size and soil-moisture retentivity (water retention curve) of this point were measured to evaluate the sediment layered condition (**Figs. 3** and **4**).

From Figure 3, all grain size distribution curves were sigmoid curve that was the feature of homogeneous sand. This result showed the vados zone consisted of fine sand and of single sediment. From Figure 4, all water retention curves showed the characteristic of sand that the water retentivity decreased rapidly by 30−50 cm suction. However, there was a slight difference in each line: especially within the range of 20−60 cm suction (enlarged view of Fig. 4). For example, the 8.0 m deep sand retained 0.23 cm^3/cm^3 soil moisture under 40 cm suction. On the other hand, the 6.0 m deep sand retained 0.07 cm^3/cm^3 soil moisture under 40 cm suction. These results suggested followings: In this vados zone, the homogeneous sands formed some microscopic sediment structures and these sediment structures had some influences on the soil -moisture retentivity.

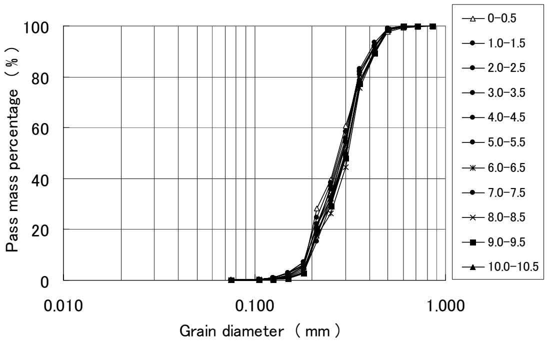


Fig. 3. Grain size in vados zone.

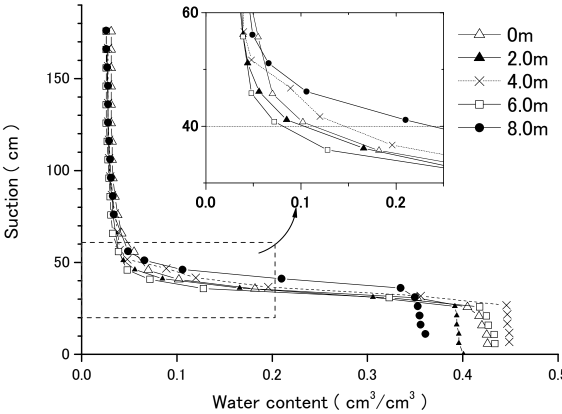


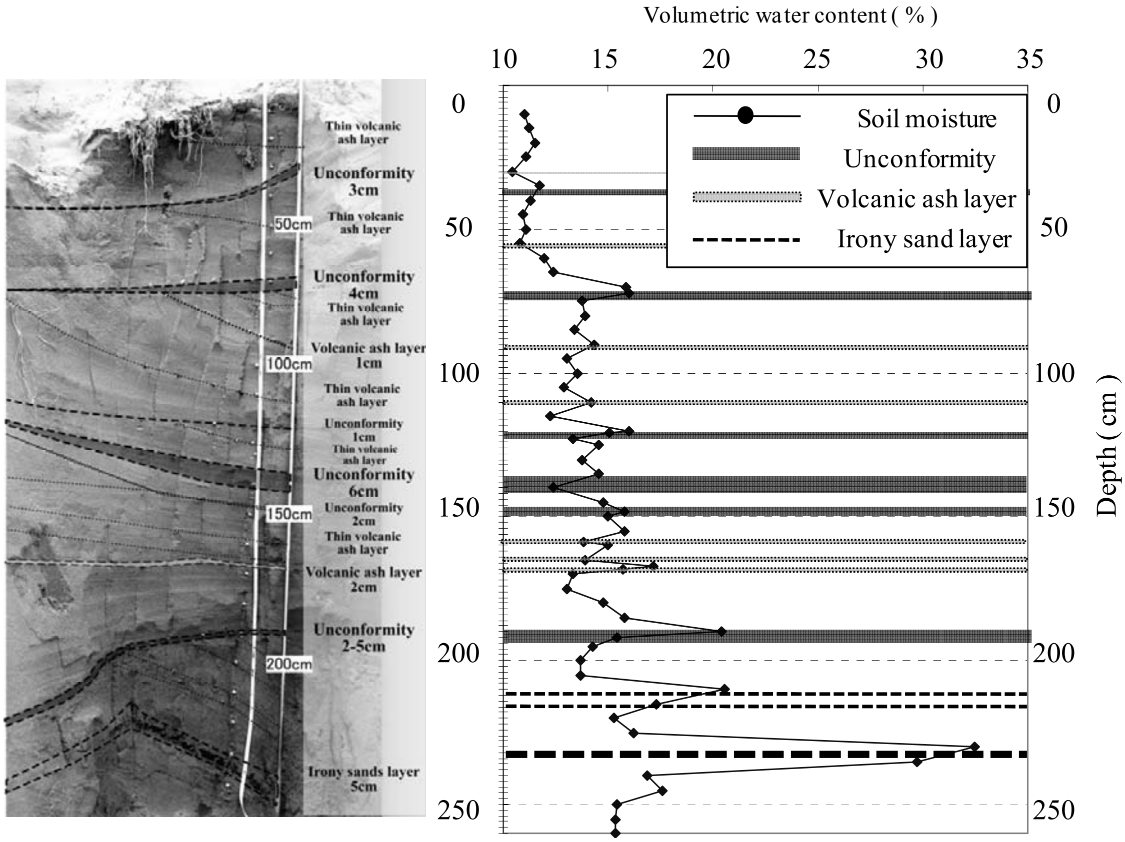
Fig. 4. Water retention curve at each 2 m depth.

3.2. Sand sedimentary structures and soil moisture profile (point 2)

With the artificial outcrop, we made detailed observation of sand sedimentary structures and soil moisture profile. The result was shown in **Figure 5**. From the visual evaluation, it was understood that the observation point had a compound cross lamina sedimentary structure. Here, lamina is the thin sedimentary structure (several mm-thickness) formed with dune growth, as Fritz and Moore (1988). And compound cross lamina has the incommensurate structure; each lamina set overlapped with no horizontal continuousness. Lamina set is formed with a number of laminae that deposited at same age. At this observation point, there were 6 clear unconformity borders of lamina set. Especially, the unconformity was remarkable of 190 cm deep. Upper lamina set deposited with 8° W and under lamina set deposited with 18−36˚W.

The soil moistures varied by depth. These variations correlated well with each lamia set. And the soil moistures were relatively high on all sedimentary borders. Especially, the soil moisture on the 190 cm deep border was 5 % higher compared with up-and-down layers. This observation results suggested that the lamina structures controlled the vertical soil moisture movement in dune.

Moreover there were 7 nondistinctive volcanic ash layers. Nevertheless these ash layers had only 1−20 mm thickness; the soil moistures were relatively high on all borders. At 167 cm deep, there was the thickest ash layer (20 mm) and the soil moisture was relatively high compared with other ash borders. Additionally, there was a definite irony sand layer in 230 cm deep. This layer also had a highly soil moisture condition. However, the WET sensor measured a relative permittivity to obtain volumetric water content and the iron sand had an effect on the sensor-output value. These results indicated that the microscopic sediment also controlled the vertical soil moisture movement as lamina structure.



(a) Compound Cross Lamina Structure (b) Soil Moisture Profile

Fig. 5. Compound cross lamina structure and Soil moisture profile.

4. Conclusions

We clarified the vertical soil moisture movement in sand dune. As the observation result, the soil moisture inside the dune was heterogeneous and had a layered structure. Then we checked the sedimentary structures finely by artificial outcrop. As the result, there was a compound cross lamina structure. The soil moistures on each cross lamina borders were constantly higher than other depths. Also, some volcanic ash and an irony sand layer were detected. The soil moistures on these layers were relatively high. Thus it became clear that the lamina structures and other microscopic sedimentary successions controlled the water movement of sand dune.

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