The Effect of Coarse Sand and Grass Roots on Wind Erosion from Desertified Lands

Yu Yi
The United Graduate School of Agricultural Sciences, Tottori University, Japan
E-mail: yuyi@phanes.muses.tottori-u.ac.jp

Okumura Takenobu and ***Sueyasu Katsumi***
Faculty of Agricultural, Tottori University, Japan
E-mail: okumura@muses.tottori-u.ac.jp

Kamichika Makio
Arid Land Research Center, Tottori University, Japan
E-mail: kamichi@alrc.tottori-u.ac.jp

Abstract: Wind tunnel tests were carried out to clarify the characteristics of progressive coarsening of sand surface with root alignments and its effect on erosion rates. Sand samples are mixtures with finer sand (d<0.84mm) and coarser sand (2.00mm>d>0.84mm, dyed black) in different percentage in weight (CSPW). Sand sample trays were exposed intermittently to wind of 3 regimes, and were photographed at five minute intervals. The earlier studies that the geometry of the mixture influences nonerodible element effect on protecting erodible surface are confirmed. We also find the positions of coarse sand play a role too. The variation in area ratio of the residual coarser particle (RCP) is responsible for the phenomena of earlier decrease in the erosion rate. When residual coarser particles on the surface were over 60%, both finer and coarser particles could be sheltered by coarser particles.
Keywords: wind erosion, wind tunnel test, grass roots, sorting, residual coarser particle

1 Introduction

Soil erosion by wind is influenced by many factors, among them surface material is a key parameter. There is a general consensus about the importance of the grain size characteristics of surface material on sediment transport by wind (Martz *et al.*, 1997). This opinion was also verified by wind tunnel experiments on selected size-distribution parent materials (e.g. Butterfield, 1991; Gillette and Stockton, 1989; McKenna-Neuman and Nickling, 1989; Rasmussen and Mikkelsen, 1991; Williams *et al.*, 1990; Willetts, 1983; Willetts and Rice, 1988). Nickling (1988), in a study of particle movement initiation by wind, suggested that the fluid threshold velocity for any sediment should be associated not only with parent material grain size but also with grain-size distribution. Gillette and Stockton (1989) found out that the nonerodible-coarser particles could increase the threshold friction velocity by sheltering the fine particles. After the publication of soil erodibility index by Chepil and Woodruff (1963), one of the size of square sieve openings 0.84 mm has been used to separate the so-called erodible from the nonerodible fractions. Martz and Li (1996) indicated that, above the threshold wind friction velocity for all surface particles, the grain-size distribution of surface particles is very similar to that of the parent material over a short time period of 10 minutes to 15 minutes. They confirmed earlier studies (Willetts and Rice, 1988) that on a non-uniform grain bed coarser particles could be more mobile than finer particles provided the wind friction velocity is higher than the threshold for the coarser particles. By these researches, some mechanisms of sorting process have become clear while still others have not been solved. The main remained issues are that most of the researches focus only on the spatial variation of grain size; very few focuses on the temporal variation of grain size. Therefore, it is necessary to reveal the mechanism of sorting process and to relate it with erodibility of bed materials, especially under the conditions of wider particle size range, lower wind velocity, and longer time period.

2 Experimental arrangement (methods)

Martz, W. L. and L. Li suggested that for better examination of the temporal variation in the grain-size distribution of the effective surface particles and interaction between particles of different sizes, experiments should be designed to maximize the sorting process. Sorting is determined by particle size and wind friction velocity, and is a gradual process. It would be preferable to choose a wide size range of particles, wind friction velocity lower than threshold for the coarsest particle, and long time period.

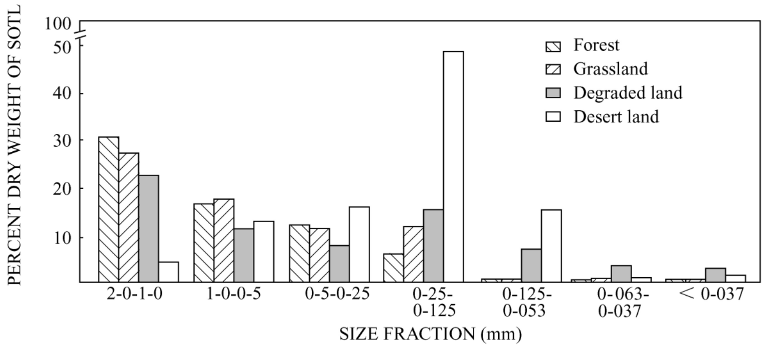

Fig.1 Size distributions of experimental materials

Experiments were conducted in an indoor wind tunnel that is 50cm×40cm (spanwise) in cross-section and 17m in length. The experiment condition was showed in Table1. In these experiments sand tray was 60cm in streamwise, 30cm in spanwise and 5cm deep. Six sand samples were prepared with local dune sand. Each of them was a mixture of finer sand (d<0.84mm) and coarser sand (2.00mm>d>0.84mm, dyed black). The size distributions of the sands and the design of coarser sand's proportion in weight (CSPW) was shown in Fig.1 and Tab.1. As Photo.1 shown grass (*Festuca arundinacea* Schreb.) root rows were aligned across sand trays in three categories of spacing. Samples were intermittently exposed to 3 wind regimes, the friction velocities (V_*) that were determined from hot-wire anemometer velocity profiles. Before the start of each experiment and at the intervals of 5-minute tests the conditions of sand trays were examined: weight losses were measured with an electronic balance and the weight of sand loss per unit erosion area (sand tray) was defined as the erosion rate (g/(cm^2 • min), Leys J.F. and Heinjus D.R., 1992); Surface configurations along three longitudinal sections were measured with an electronic digital caliper; the eroded surface was photographed by the digital camera system mounted on the tunnel roof. The photographs taken were scanned and analyzed to calculate the area ratio of residual coarser sand (black area) using an analysis program on personal computer. The ratio of the area residual coarser particles occupied to the total area of sand tray was defined as the residual coarser particle (RCP).

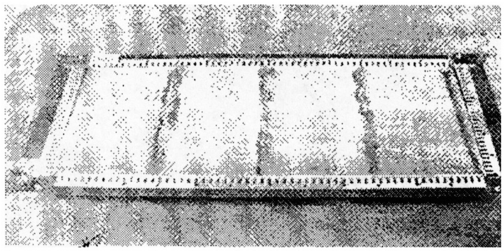

Photo 1 Roots rows in sand tray (3rows)

Table 1 Profile of experiment condition

Sand tray	length:60cm.width:30cm depth:5cm
CSPW	0%,10%,20%,30%,40%,50%
Roots rows	2,3,5rows
Distance of rows	20cm,15cm,10cm
Friction velocity	24cm/s,32cm/s,39cm/s
Time intervals	5min+5min+5min+5min+5min+25min+5min

CSPW: coarser sand's proportion in weight.

3 Results

3.1 Sand surface configuration and erosion rate

The analysis of the tests in the three kinds of friction velocities, demonstrated the most of wind erosion intensities were reduced in the initial period of about 5 minutes. On the sands with rows of grass roots, erosion depth was reduced sooner than without grass roots. In the rooted samples, mounds and depressions appear on the surface, reflecting the presence of the aligned rows, and the relief is lower where the number of rows is greater. With the CSPW increased, the wind erosion intensities are also reduced. This may be responsible to (a) shortening of equivalent length along prevailing wind erosion direction by dividing erodible sand surface; and (b) formation of less erodible topmost layer composed with the coarser creep particles restrained by exposed roots.

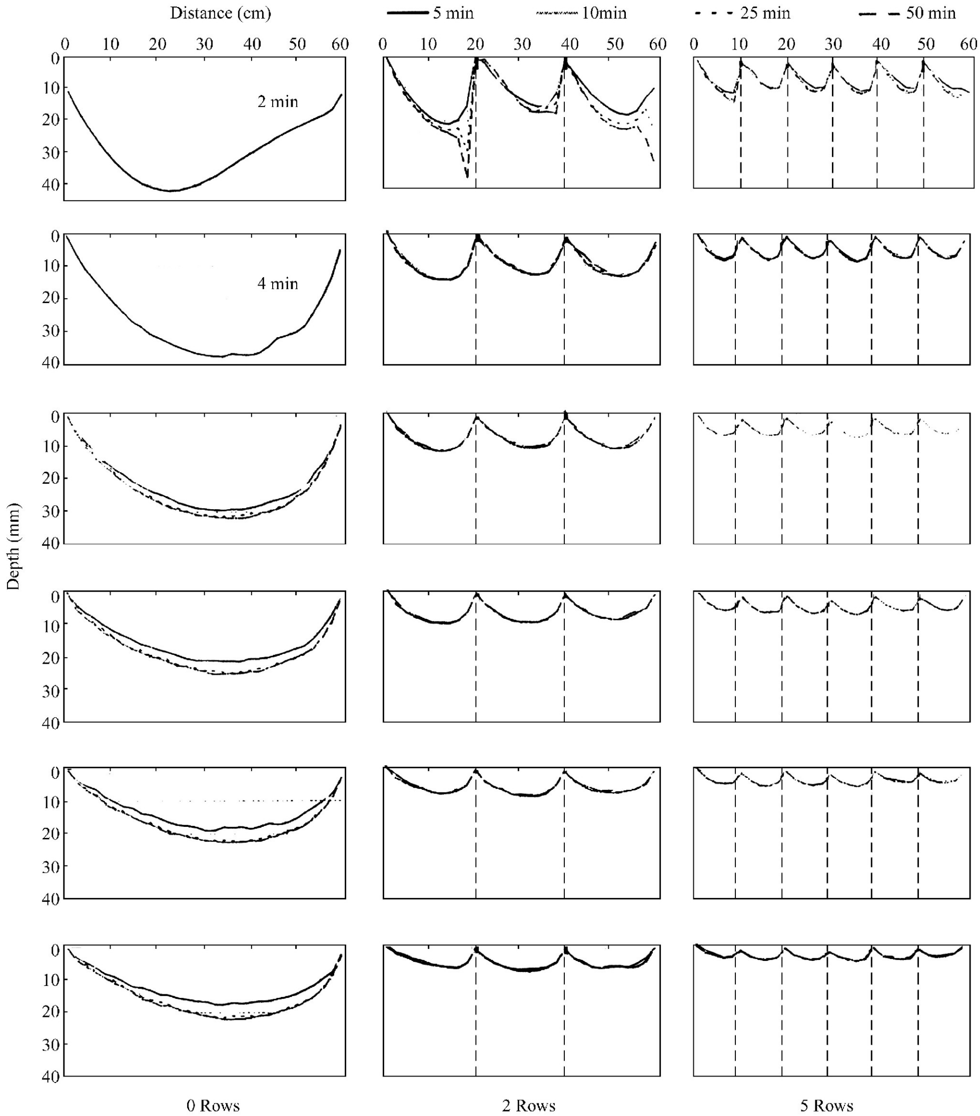

Fig.2 Surface configurations under friction velocity 39cm/s (Vertical lines indicate roots rows, CSPW: coarser sand's proportion in weight)

As shown by Fig.2, the wind erosion intensities are reduced in the initial period of about 5 minutes in friction velocity 39 cm/s except two cases of CSPW 0% and 10% without grass roots. Without the protection of nonerodible particles and roots systems, fine particles are quickly blown away. The more the CSPW is, the less the erosion depth is. Coarser sands help stabilize sandy surface and reduce erosion depth. Aligned grass roots can effectively affect the process of wind erosion remolding sand surface.

Fig.3 shows variations in erosion rate over time in the case of 39 cm/s of friction velocity. On the rooted sand surface, erosion rates gradually reduce over time except two cases with 0% and 10% of CSPW which were emptied in only 2 minutes and 4 minutes. The presence of larger number of grass rows causes the erosion rate to diminish with time and finally results in almost no particle movement. Sand layer in CSPW 10% can effectively reduce erosion rate but cannot stop movement of erodible particle, indeed.

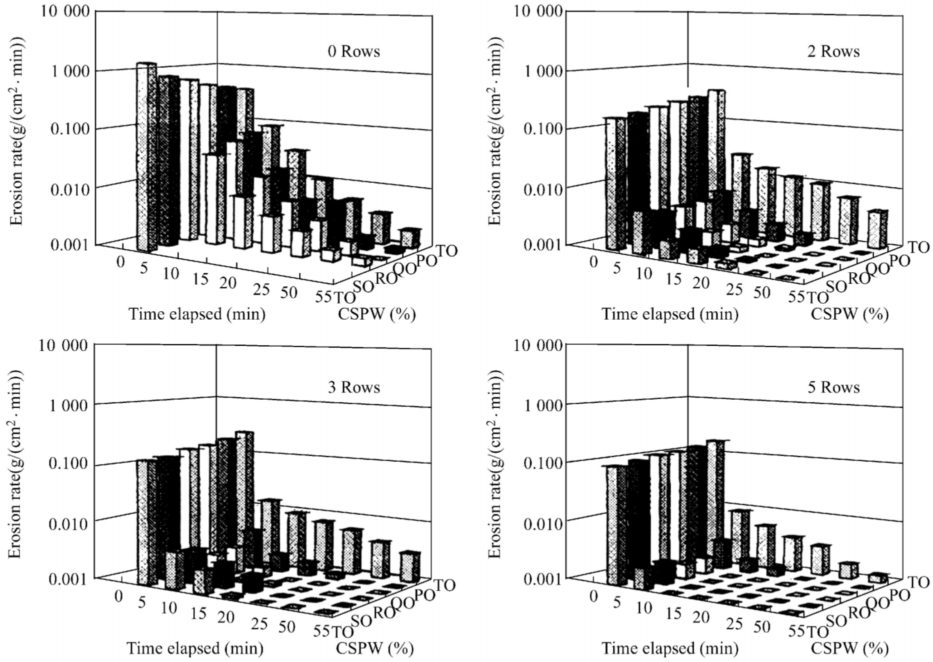

Fig.3 Variations in erosion rate over time under friction velocity 39 cm/s

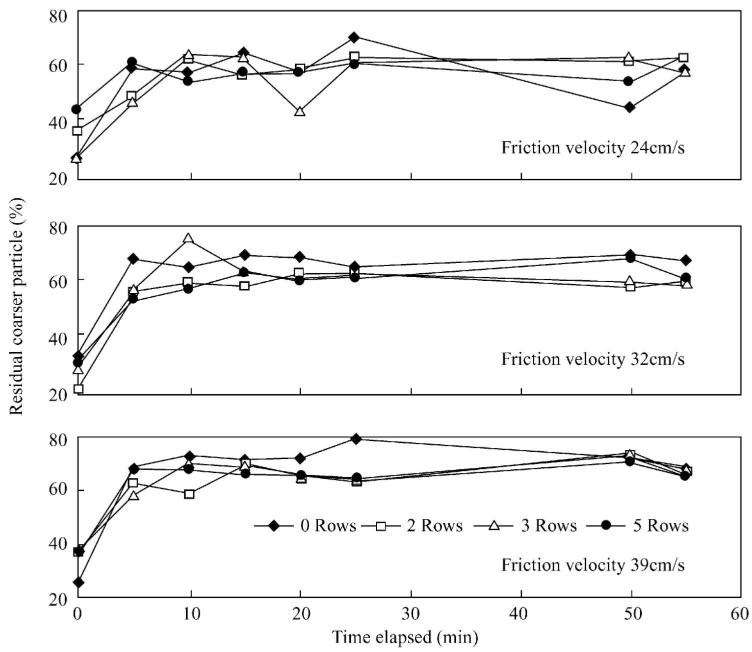

Fig.4 Changes in residual coarser particle (RCP) in case of CSPW 50%

3.2 Changes in residual coarser particle (RCP)

As Rasmussen, K. R. and Mikkelsen, H. M. (1991) pointed out, when grains are gradually exposed to the air flow, the average speed of creeping grains is less than that of saltating grains the latter may progressively be blown away from the bed, leaving the creeping grains as a residual “armouring”. In the present study, whichever sand tray included the root system or not, selective erosion (sorting) is recognized, that is, the particle size distribution was coarser in the surface layer than the underlying parent material. RCP increased in the initial period of about 5 minutes, then gradually kept steady until the surface goes stable. Fig.4 shows the process of wind erosion in the case of CSPW 50%, when RCP reaches about 60%, erosion rate declines and the sand surface goes to be stable. The variations of erosion rate (Fig.3) and RCP (Fig.4) under wind flows implicate that erosion rate and RCP was cause-result relationship. In the most of cases erosion rate reached maximum in the initial period of 5 minutes, the RCP did so. Consequently, RCP restrains the further development of erosion.

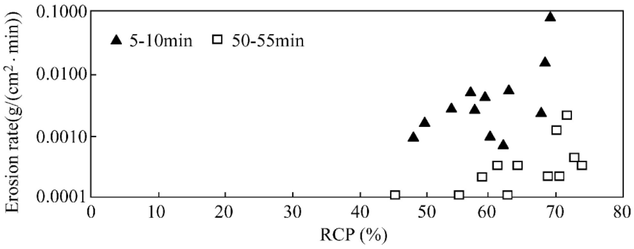

Fig.5 Differences of erosion rate between 5 min to 10 min. and 50 min. to 55 min. of CSPW 50%

3.3 Orientation of coarser sand

With the exposure time lapsed fine particles goes first and erosion rate goes down, then coarse particles are dragged out of the trays. From Fig.4 we find the magnitudes of RCP almost remained steady after 5 minutes. Meanwhile, Fig.3 indicated the erosion rate in the period of 5 minutes—10 minutes was different with that in the period of 50 minutes—55 minutes. Comparison of the two magnitudes in case of CSPW 50% as showing in Fig.5, even though the RCP were in the same level, the erosion rate in the period of 5 minutes—10 minutes was bigger than that in the period of 50 minutes—55 minutes. Detailed examination of how the positioning of coarser particles on surface changed over time between 5 minutes to 55 minutes, reveals oriented positioning of coarser particles on sand surface with the wind direction instead of disorder arrangement (Photo 2). We refer this kind positioning of assembled coarser sands as “oriented assemble”.

We observe that this kind of positioning (packing) of the assembled coarser sands performed some effects on the stability of an eroded surface. We confirm the earlier studies that the coarser particles shelter the finer particles, and find that the coarser particles are also sheltered by “oriented assemble” acting as a whole structure. Photo 2 also shows that the assembled coarser sands are more effective on protecting erodible sands than individual coarse particle.

Photo 2 “Oriented assemble” of coarser particles on stabilized surface

4 Conclusions

The roles of coarse sand and aligned grass roots to reduce wind erosion have been confirmed. Wind erosion from a mixture of erodible and nonerodible particles is actually a process of sorting. As a result of fine particles being first blown away residual coarser sand forms a resistant layer to on going erosion. The more coarser particles are, the less the erosion depth is. "Oriented assemble" *i.e.* oriented arrangement of residual particles are a result from sorting by airflow, conversely, help stabilize the surface and prevent from further erosion. Aligned grass roots can greatly resist wind erosion from sands. A combination of coarse particle layer and grass roots can effectively control wind erosion from sand surface.

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