Laboratory experiments for sediment deposition and detachment in a rill under different vertical hydraulic gradient conditions

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Introduction

Soil erosion and sediment runoff have led to agricultural and environmental problems throughout the world. Not only on-site effect of decreasing soil fertility, but also various ecosystems have been damaged due to oversupply of sediment from agricultural zones.

Many researches have been done about the soil erosion. One of great achievement was Universal Soil Loss Equation, USLE (Wischmeier and Smith, 1978) in 1960s.

After the development of USLE, Water Erosion Prediction Project, WEPP (Flanagan and Nearing, 1995) was developed in 1980s. This model is the process based model including various theories of soil erosion.

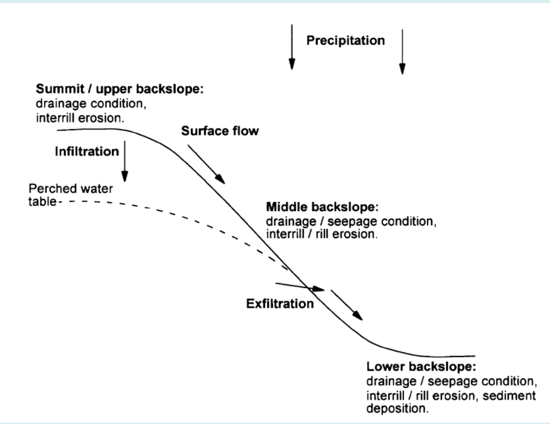
However, there is much left to study about soil erosion mechanisms.

Objective

In this study, laboratory experiments were conducted to estimate the sediment deposition and detachment in a rill under different vertical hydraulic gradient conditions.

Experiments were focused about sediment redetachment subsequent to deposition. After the deposition, does sediment delivery rate increase? Is increasing of the rate related to previous deposition amount?

In general, seepage condition takes place in the middle or lower part of slope. Changing from drainage to seepage is effected by the level of perched water table. Sediment dynamics (deposition and detachment) are quite different in such conditions (Nouwakpo et al. 2010).

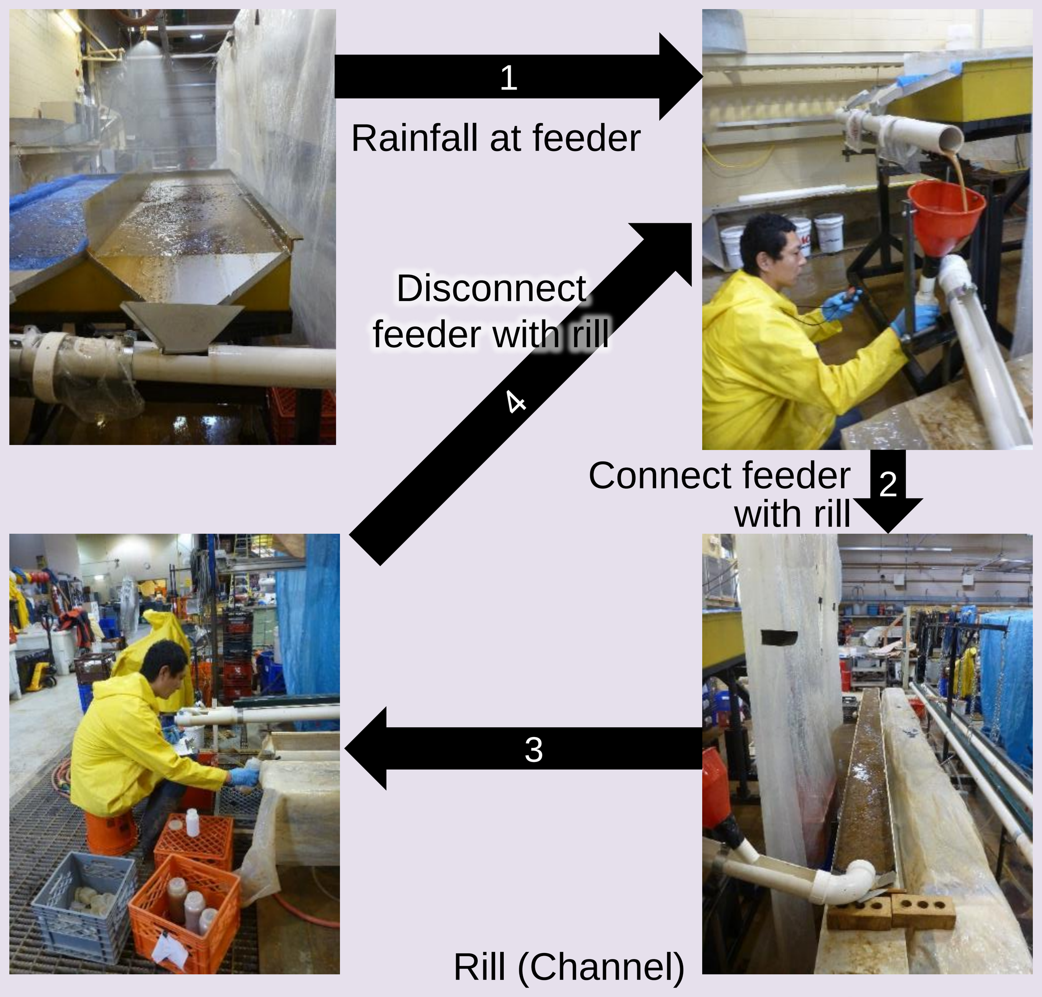


Hillslope position, hydrologic condition and erosion processes (Gabbard et al. 1998)

Materials and Methods

Sediment feeder
L:1.8m, W:1.2m, D: 0.3m
Slope: 5%, 25mm/h rainfall

Sampling at feeder
2 samples for beginning
2 samples for ending

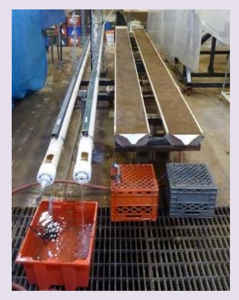


Sampling at rill
4 or 5 samples

Rill (Channel)
L: 5.0m, W: 0.25m, Slope: 2.3%
Bulk density: .15 – 1.25g/m^3
Flow rate: 0.10 – 0.11 L/s
No rainfall

Soil: Miami Clay Loam
Texture: Sand 21%, Silt 50%, Clay 29%
Organic matter: 2.5%

Seepage condition was represented by using water circulation system.
Seepage rate: 0.005 L/s



water circulation system for making seepage

Experiment procedure

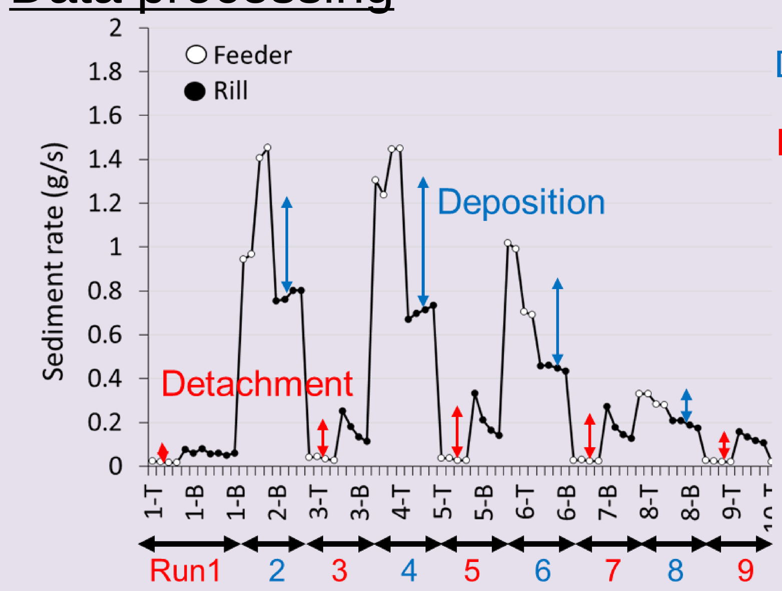
The amount of supplied sediment was controlled by changing the soil surface cover of the feeder using fabric.

Order of runs (2nd season, 25mm/h feeder rain, No rill rain)

Run	Feeder cover %	Hydrology	Sediment
1	100 (Clear water)	Drainage	Erosion (as reference)
2	50 (High feed)	Drainage	Deposition (High)
3	100 (Clear water)	Drainage	Redetachment + Erosion
4	62.5 (Mid feed)	Drainage	Deposition (Mid)
5	100 (Clear water)	Drainage	Redetachment + Erosion
6	75 (Low feed)	Drainage	Deposition (low)
7	100 (Clear water)	Drainage	Redetachment + Erosion
8	87.5 (Very low feed)	Drainage	Deposition (very low)
9	100 (Clear water)	Drainage	Redetachment + Erosion

Run	Feeder cover %	Hydrology	Sediment
10	100 (Clear water)	Seepage	Erosion (as reference)
11	50 (High feed)	Seepage	Deposition (High)
12	100 (Clear water)	Seepage	Redetachment + Erosion
13	62.5 (Mid feed)	Seepage	Deposition (Mid)
14	100 (Clear water)	Seepage	Redetachment + Erosion
15	75 (Low feed)	Seepage	Deposition (low)
16	100 (Clear water)	Seepage	Redetachment + Erosion
17	87.5 (Very low feed)	Seepage	Deposition (very low)
18	100 (Clear water)	Seepage	Redetachment + Erosion

Data processing



Example of data

Deposition = Sediment from feeder – Sediment from rill

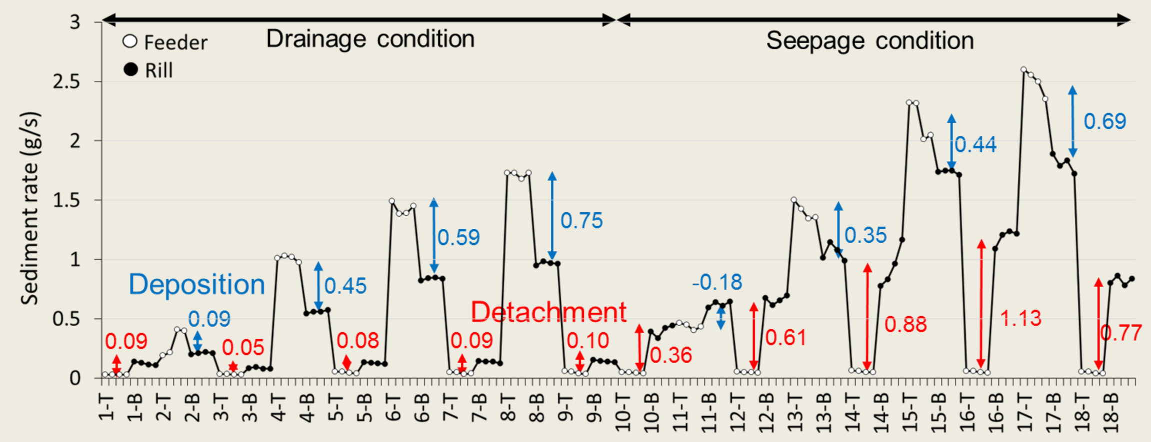
Detachment = Sediment from rill – Sediment from feeder
= Erosion of original soil + Erosion of deposited soil

It is assumed as constant.
Detachment of Run1

It is assumed as variable.
Difference of detachment of Run1 with Run 3, 5, 7, 9.

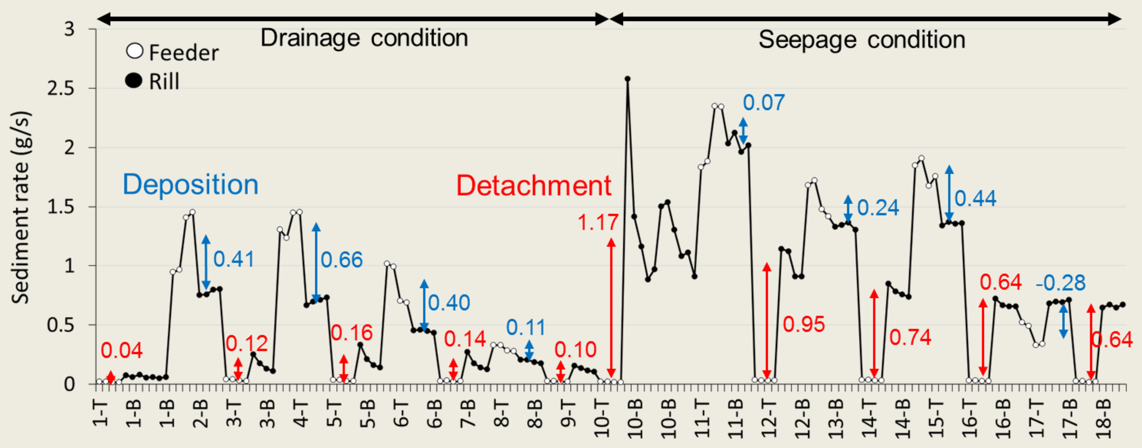
Results and Discussions

Results -1st season-



Sediment delivery rate of all samples in 1st season
"B" means bottom at rill, "T" means top at rill (from feeder).

Results - 2nd season -

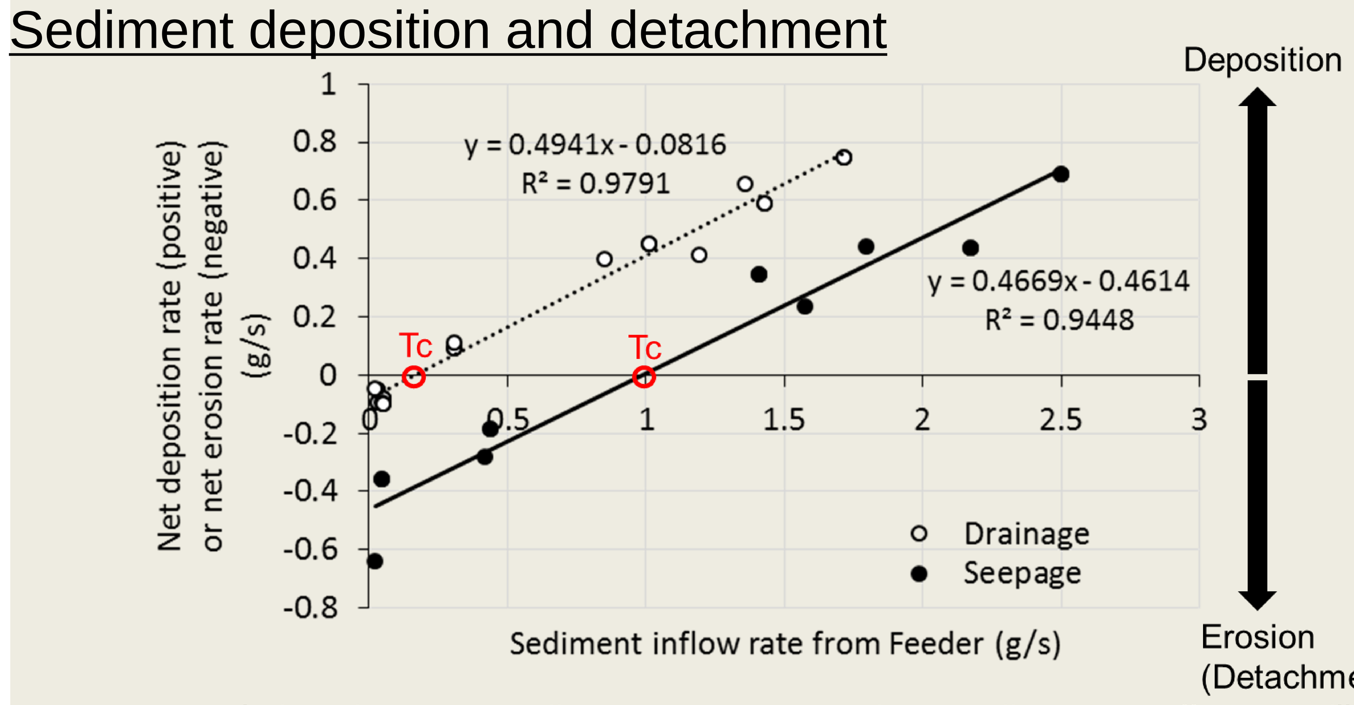


Sediment delivery rate of all samples in 2nd season
"B" means bottom at rill, "T" means top at rill (from feeder).

- Deposition was increased as increasing of sediment supply.
- Deposition was larger under the drainage condition comparing seepage condition.
- Detachment was larger under the seepage condition comparing drainage condition.
- Redetachment was found under the drainage condition. On the other hand, erosion of original soil was found under the seepage condition.

- These runs were conducted in back order of former experiment so as to be sediment supply large to small.
- The results were same manner of former experiment.

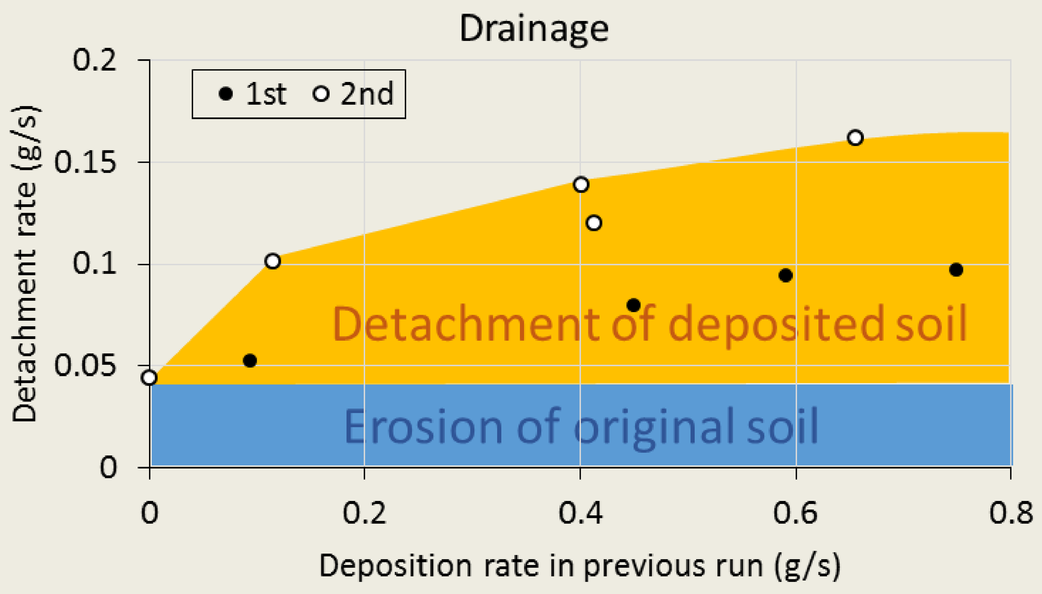
Sediment deposition and detachment

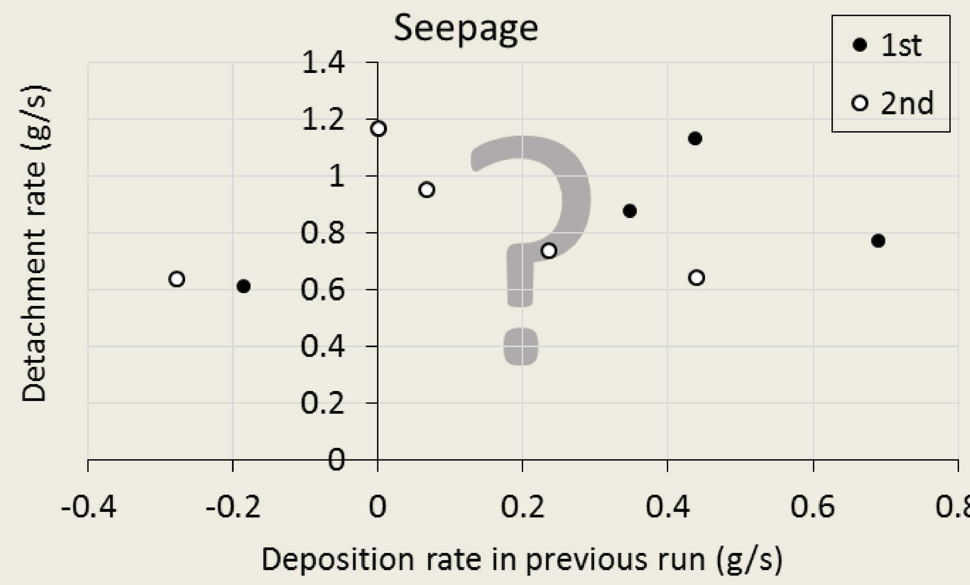


Relations between sediment runon rate and net sediment runoff rate at rill

- As increasing sediment from feeder, sediment in rill shifted from detachment to deposition.
- The relationship of sediment inflow rate from feeder with net sediment rate in rill was linear.
- Deposition is easy to occur under the drainage condition.
- Sediment transport capacity, Tc was 0.66 g s^{-1} m^{-1} under drainage condition and 3.95 g s^{-1} m^{-1} under seepage condition.

Sediment detachment

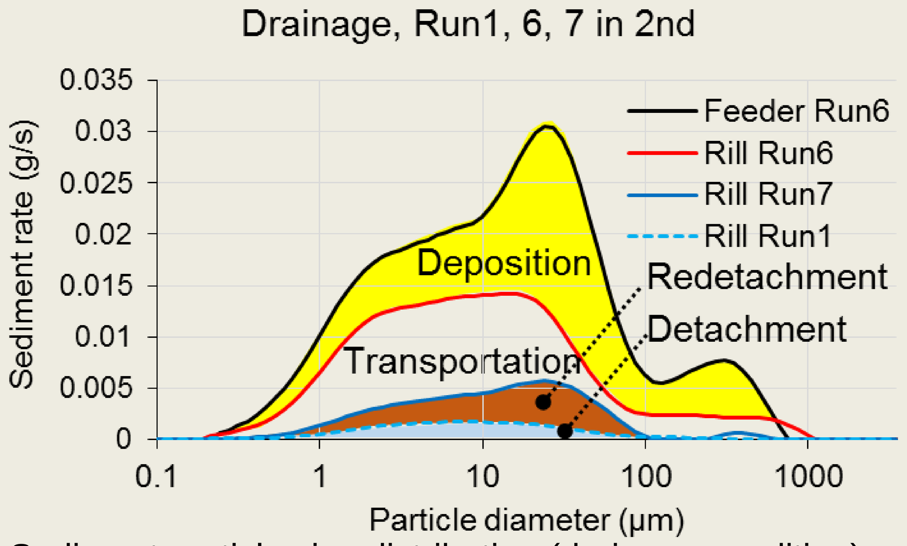




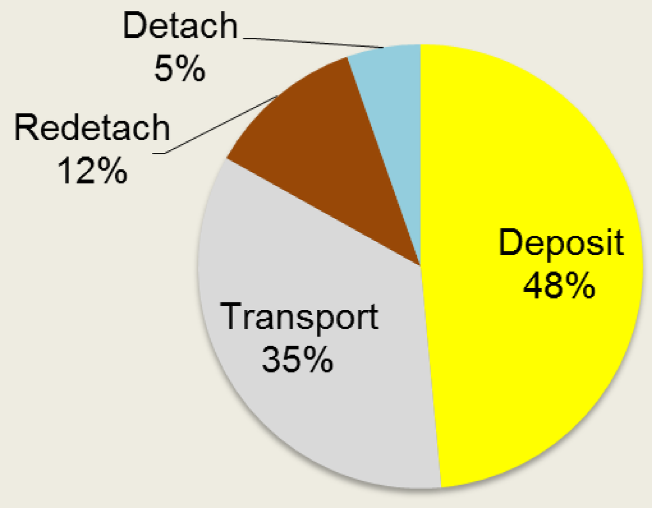
Relation between deposition rate and detachment (Left: drainage condition, Right: seepage condition)

- Detachment rate was gradually increased with deposition rate under the drainage condition. Detached sediment might be included redetached sediment from deposited soil. The ratios, redetachment/deposition were from 18% to 50% in 2nd runs.
- On the other hand, redetachment under the seepage condition was not shown obviously. It was because erosion of original soil was much larger than detachment of deposited soil.

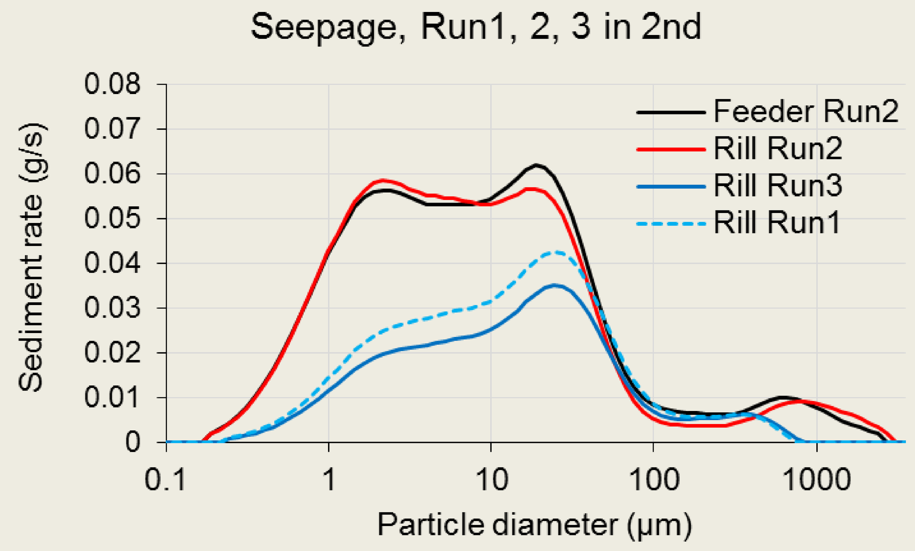
Sediment particle size distribution and sediment dynamics



Sediment particle size distribution (drainage condition)



Ratio of sediment behaviors (drainage)



Sediment particle size distribution (seepage condition)

- Fine sediment, less than 100μm, was easy to transport in the rill (White field in left figure).
- Coarse sediment, up to 1000μm (1mm), was tend to deposit in the rill (Yellow field in left figure).
- In the following run, deposited sediment was detached (redetachment) in the range from 0.5μm to 100μm (Brown field in left figure). The most frequent size of redetached sediment, 30μm, was same with the most frequent size of deposited sediment.
- Ratios of each sediment behavior were shown in middle figure. Deposition occupied large part in sediment dynamics under the drainage condition.

- Under the seepage condition, difference of particle size distribution was not seen comparing Feeder Run2 and Rill Run2, Rill Run3 and Rill Run1 in right figure.
- These results support deposition and redetachment were relatively small under the seepage condition compared with drainage condition.

Conclusions

- Deposition was increased with increasing of sediment supply under the both vertical hydraulic gradient conditions. Deposition under drainage condition was larger comparing seepage condition.
- Detachment under the seepage condition was larger comparing drainage condition. Detachment rate was increased with increasing previous deposition rate under drainage condition.
- Detached sediment was included redetached sediment from deposited layer under drainage condition. The ratios, redetachment/deposition were less than 50%. Redetachment under seepage condition was not shown obviously. It was because the erosion of original soil was much larger than the erosion of deposited soil.
- Sediment, up to 1000μm, was deposited in the rill under drainage condition. Deposited sediment was detached (redetachment) in the range from 0.5μm to 100μm under this condition.

Acknowledgements

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