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Effects of Driftwood on Deposition-Fan Erosion of Debris Flows†

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Abstract: Debris-flw Flume experiments of deposition and fan formation have been mostly conducted over hard non-porous plane. However, the surface a debris-flow travels on is influencing the dynamics of the flow and the deposition process as it has been shown recently. We have argued that (1) water exchange occurs with the surface and (2) material exchange (erosion and deposition) is also occurring in the deposition area. Continuing from this set of experiments, we are now attempting to clarify the role of debris in the debris-flow, one of them which are often neglected is wood debris. In the present contribution, the authors attempted to quantify the role of wood debris on deposition and deposits in a controlled environment. For the present experiment, we used a flume with a reception pan that is 185.6 cm length × 95.6 cm width, with walls 26.2 cm high. The channel is 400 cm long, 25.0 cm high, and 18.5 cm wide. Repeating earlier experiments without wood debris, the receiving pan was spread with a 1–2 cm thick sediment layer. In the channel, a set of wood debris were erected. From this setup, the authors ran multiple experiment setups with 5 repeats of the same experiment each time. Using video-camera recording of the flow, photogrammetry of the deposits. The results have shown that driftwood starting from the flume tends to end on the sides of the fan, while the driftwood starting on the fan ends at the toe of the fan. When the material on the receiving pan is dry, then the driftwood also concentrates at the toe of the fan instead of the sides. This natural dam blocks the water, and the sediments on the fan are spreading more evenly. The difference between erosional and depositional areas is less contrasted. Thus, the starting location of driftwood and the characteristics of the material on the fan then controls the spatial distribution of the driftwood deposits and this distribution in turn modifies the erosion/deposition balance over the fan.

Keywords: driftwood; wood debris; debris-flows; flume experiment

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1. Introduction

Debris-flows are mixtures of water and debris of different types and shapes, and both their velocity and the debris are a hazard to individuals and infrastructures [1,2]. When the flow leaves the steep-mountain slopes to the connecting downstream valley, the channel gradient change and the confined channel spreading wider leads to the generation of a debris-flow fan, which can be differentiated from fluvial fans by the Melton index [3]. It ensues a relation between the fan morphometry and the watershed characteristics, both for rainfall-triggered [4] and earthquake-triggered debris-flows [5]. Despite a breath of research on this topic, there is still limited work that has investigated the role of driftwood on debris-flow fan formation and morphology [6], with most of the research concentrating on the processes within a channel [7], and how to stop the debris using open-type and slit Sabo-dams [8,9].

This interest in countermeasures mostly arise from the fact that driftwood in river channels is a consequent hazard for forested mountain channels and connected downstream rivers [10]. Driftwood in river corridors and in the floodplain has attracted most of the attention of scientists, with numerous models working from the wood distribution in open channels and in the floodplain. This body of research has mostly grown from the hazard that wood debris creates for dams and other hydraulic infrastructures, eventually increasing flood disaster risk [11].

Despite of this large body of research on driftwood in rivers, the work linking debris-flow and driftwood is more limited and the role of driftwood on controlling the sedimentation and erosion process on a fan is still a research gap that needs bridging. In the present study, the authors have therefore designed a set of experiments with the goal of understanding the role of driftwood in combination with debris-flow deposition over saturated substratum or dry substratum.

2. Methodology

To reach this objective, we have built a straight and sloped flume that is connected to a deposition pan. The water is provided by a valve-operated water-tank of 8 L. The flume length is 380 cm × 19.0 cm width, with a 15 degrees angle, while the receiving pan is 185.6 cm long × 95.6 cm wide (Figure 1).

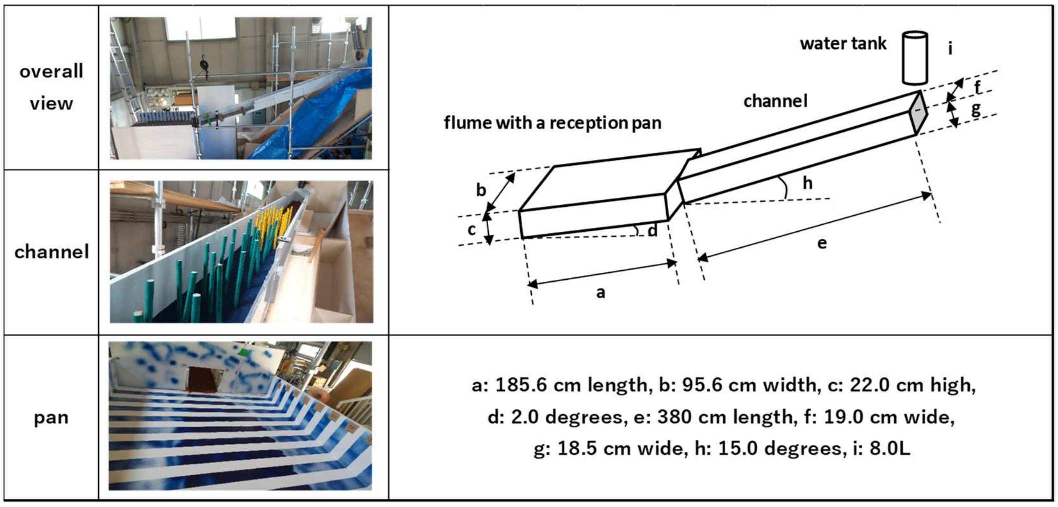

Figure 1. Flume used for the present research, describing the setup and its size.

Inside the flume (Figure 1), 12 kg of calibrated colored-sand was set and 25 kg was spread to make a 2 cm thick layer in the receiving pan. The calibrated sand in the receiving pan was either wetted with 4 L of water (experiment 1 and 2) or dry (experiment 3).

We have used 60 wood sticks (20 cm long and 8 mm diameter) simulating the driftwood. We added the sticks to the channel in all experiments, while we added another 20 wood sticks to the receiving pan in only experiment 2.

When placed in the flume channel, the 60 wood sticks were divided into three different colored sticks. The blue sticks were located 50 to 110 cm from the downstream exit of the flume channel, the green ones, between 110 and 170 cm and finally the top ones between 170 and 230 cm. This division was used to understand which sticks arrive first, and how they mix with one another. Including the coloring tape, the density of the driftwood varied between 0.35 to 0.42 g/cm^3. These values were used to reproduce the values of Japanese Sugi (*Cryptomeria Japonica*) and Hinoki (*Chamaecyparis obtusa)*, which are 0.38 and 0.41 g/cm^2 respectively. The three sets of experiments, 1, 2 and 3 have been performed with 5, 5 and 3 repeats respectively.

Each experiment was triggered using the valve-operated tank at the top end of the flume, releasing 8 liters over 3 seconds (0.0026 m^3/s).

Each experiment was surveyed during flow using video cameras located at 4 different locations over the flume, then the position of the driftwood on the deposited fan was mapped using sets of photographs to create an orthophotograph using structure from motion. Finally, we opened transversal trenches across the fan to measure its thickness along a central line starting from the head to the toe of the fan. We measured values every 10 cm up to 100 cm from the channel inlet.

3. Results and Discussion

3.1 Distribution of the Driftwood Deposits

Results of the experiments have shown that the driftwood is pushed and accumulated downstream, mostly in experiments 3 when the sediments on the receiving pan are dry. The constantly high-numbers show 70% concentrating downstream with remaining 10% and 20% on the side. For experiments 1 and 2, the percentage of driftwood accumulated at the toe of the fan were respectively 30% and 60%, with the high percentage representing the driftwood on the receiving pan from the very beginning (Table 1).

Table 1. Averaged data for each experiments showing the position of the wood deposits. Experiments 1 and 2 are made of 5 repeats each and experiment 3 is made of 3 repeats.

Experiment nb	Right-side of the fan (%)	Left side of the fan (%)	Downstream (%)
1	35	35	30
2	30	10	60
3	10	20	70

From the visual and video observations, we can determine that the driftwood was pushed aside by the water in experiment 1, while the dry sediments in experiment 3 absorbed a portion of it. Therefore, instead of the water pushing the driftwood aside, the water level at the surface of the fan dropped rapidly and the driftwood remained in the middle section of the toe of the fan. This explains the main difference between experiment 1 and 3. A high proportion of driftwood also accumulated downstream in experiment 2, and in this case we estimated that:

(a) the tree moving after being toppled down, a portion of the water escape the fan before transporting the driftwood and there is then less water available to move the trees aside This is a timing issue; and

(b) as the driftwood is not travelling in the flume, it does not gain momentum from the movement in experiment 2, and thus the driftwood just slightly move towards the toe of the fan.

3.2. Effects of Driftwood on the Fan

In order to link the driftwood distribution pattern and its effect on the erosion and deposition (i.e., the distribution of energy on the fan). On all three types of experiments (Figures 2, 3 and 4), erosion removed all the sand at the very head of the fan, mostly due to the effect of the slope angle change. For experiment 1 (5 repeats), erosion dominates the 40 cm from the head of the fan, and towards the toe limited deposition (Figure 2). In experiments 2 and 3, the erosion extended only to the first 20–30 cm from the head of the fan (Figure 3 and 4).

Deposition rises above the 2 cm clearly after 60–70 cm in experiments 1, while in experiments 2 and 3, the deposition occurs much higher on the fan around 30–40 cm., and while deposition increases in experiment 1, it remains constant on average in experiments 2 and 3 (figures 2, 3 and 4).

It can be argued that the division in these results is the result of the position of the driftwood, which has barred the flow in experiments 2 and 3, while in experiments 1 the driftwood is mostly located on the sides. This spatial distribution of the driftwood created a micro- natural dam, so that the water remained at lower velocities on the fan allowing for a more regular deposition, in the like of shallow-water sedimentation. Experiment 1, by opposition showed erosion and deposition that is characterized by water flowing out of the fan at higher velocity and creating more variability in the erosion-deposition balance and eroded a larger length of the deposits on the fan.

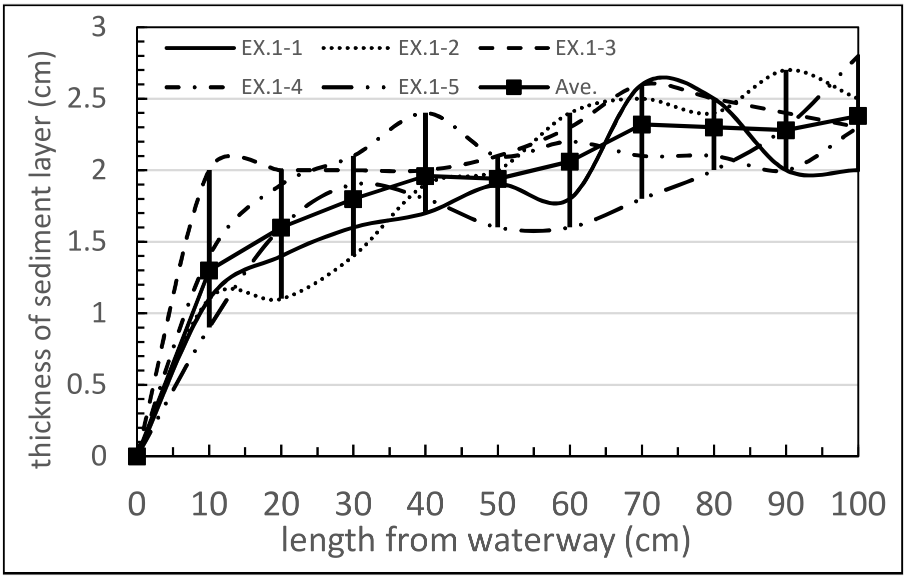

Figure 2. Thickness of sediments on the receiving pan for experiment 1, with the data separated by sub-set and with the average.

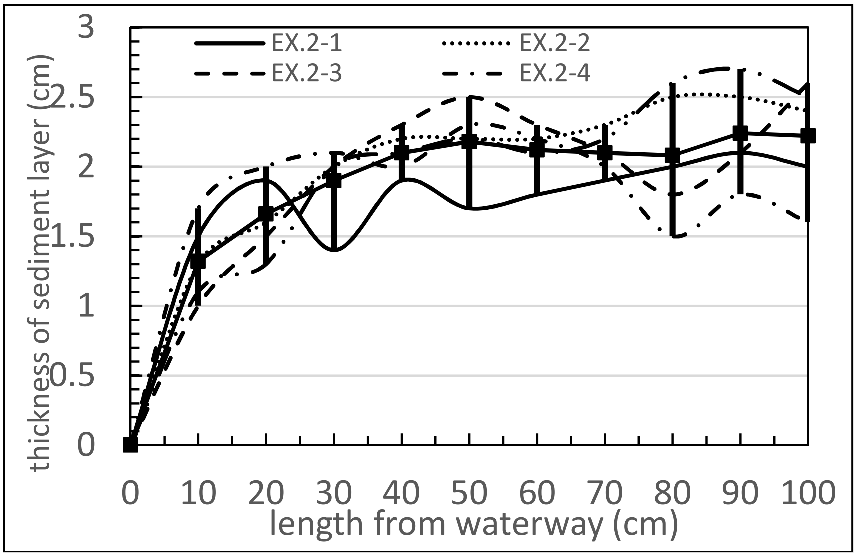

Figure 3. Thickness of sediments on the receiving pan for experiment 2, with the data separated by sub-set and with the average.

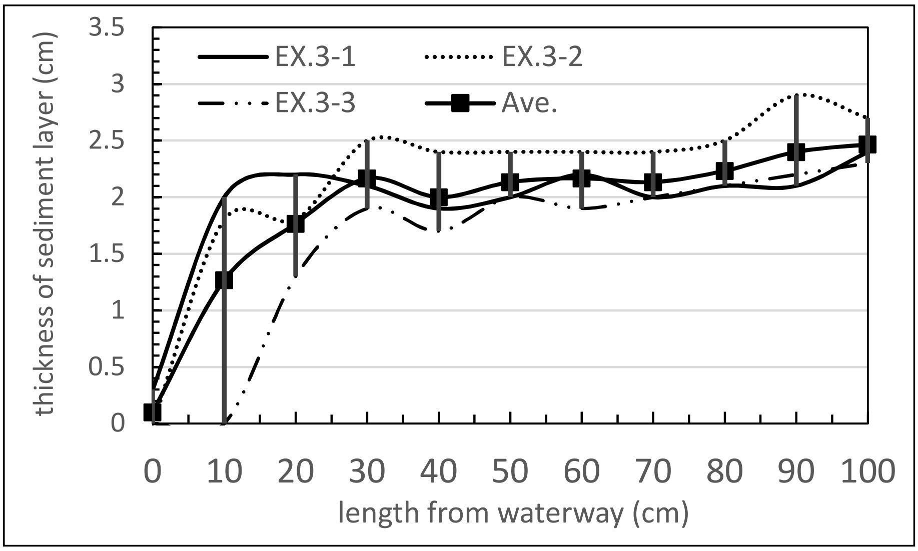

Figure 4. Thickness of sediments on the receiving pan for experiment 3, with the data separated by sub-set and with the average.

4. Conclusion

In conclusion, from the 13 experiments (5 × 1 and 5 × 2 and 3 × 3) we could show that wood debris do not stop in the same location depending on how fast they travel and how much dewatering is occurring. The position of the driftwood on the fan can also create a micro- natural dams, which then modify the surface morphology and deposition of sediments. This suggests that driftwood located over a fan may be used to reduce the effects of sediment hazards, and considering leaving the driftwood on fans instead of removing it could help control forthcoming sediment hazards and flood impacts.

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