# Modelling channel stability in experimental river systems

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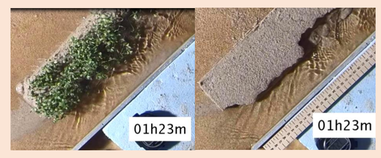
## Background

- Climate change suggests increases in the magnitude and frequency of rainfall events, with greater likelihood of fluvial flooding.
- The nature of fluvial morphological response is uncertain and can best be explored through modelling.
- Physical modelling has so far primarily examined single flood events, whereas a sequence of flood events can enhance morphological change and overcome channel stability thresholds in order to shift to a different system.
- Channel stability is heavily dependent on vegetation, and, when vegetation grows channel stability changes over time. An increase in flood frequency can reduce vegetation recovery opportunities.
- Bank erosion experiments have the potential to quantify the effects of surrogate vegetation and EPS in physical fluvial experiments.
- Surrogate vegetation growing is relative time consuming and a limiting factor in physical modelling.
- Extracellular Polymeric Substances (EPS) have been shown to enhance cohesion of sediment.

## Aims

- Understand behaviour of surrogate vegetation for flume experiments
- Understand the influence of seed density and age of vegetation.
- Understand whether EPS is suitable to represent vegetation in regards to channel stability.

Interested in time lapse ➔ movies?




## Methodology for bank erosion experiments

- 10 cm wide, 2 cm thick trapezoid block of sediment (fig 1)
- Constant water flow (470 l/h)
- 434 µm sediment (1 kg)
- 6 vegetation settings
- 9 different EPS settings
- 10 replicates of each setting

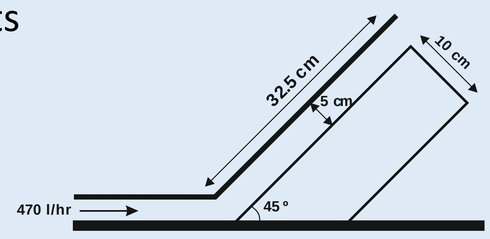



*Fig. 1: Schematic overview bank erosion experiments*

Two different **EPS** were used, Xanthan Gum and Carrageenan. EPS were dry-mixed with the sediment before being mixed with water.
EPS-sediment mixture was made in-situ, and experiments were started within 15 minutes.

*Fig. 2: Growing basin for vegetation.*

**Vegetation** (Alfalfa, *Medicago Sativa*) was grown under controlled conditions, T = 18-20 °C, with natural sunlight lamp in a separate basin with saturated sediment bed.
Unprepared seeds were manually planted on saturated sediment. Samples were moved to flume after 7, 10 or 13 days and erosion experiments were started within 1 hour.

## Image processing in Matlab

- 30s time lapse with using GoPro camera from above.
- Convert to rectified greyscale image.
- Use threshold to convert to binary image.
- Use interpolation to smoothen image (fig 4).
- Determine boundary of the sediment block.
- Compute block volume over time relative to fixed back wall (fig 3).

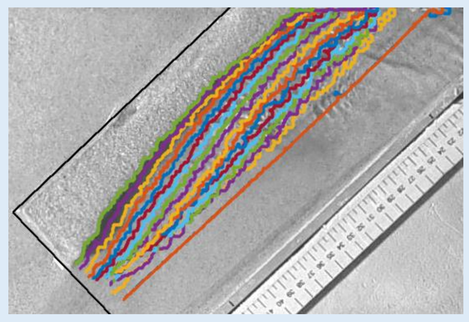


*Fig. 3: Boundary line of sediment block over time and back wall (black).*

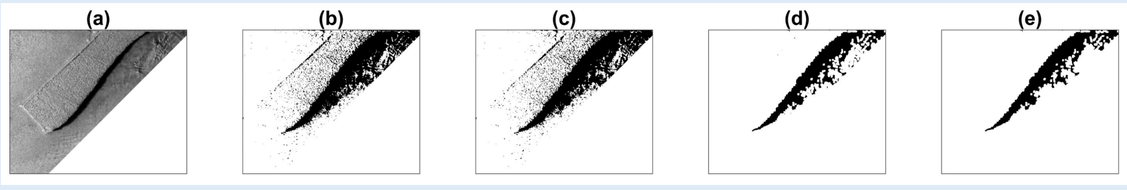



*Fig. 4: Intermediate products of image processing from greyscale image to boundary line of the sediment block.*

## EPS/Chemical Surrogates

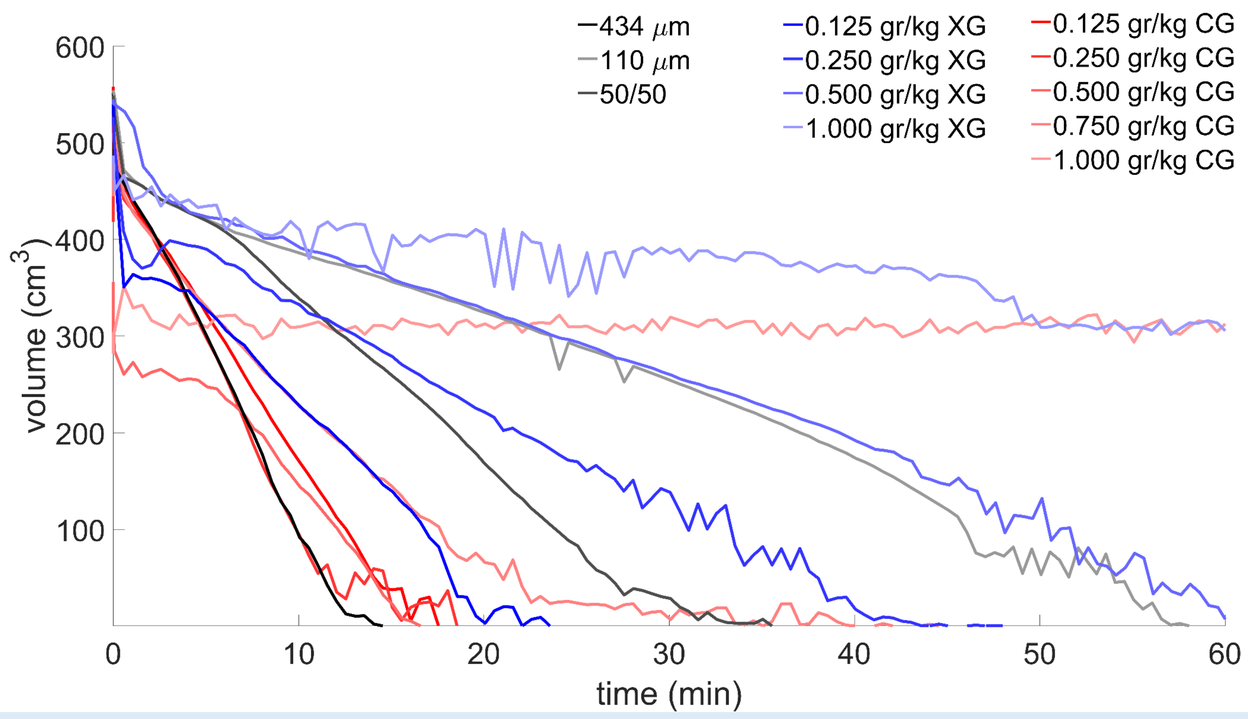



*Fig. 5: Averaged block volume over time for both EPS, Xanthan Gum (red) and Carrageenan (blue), for different dry weight percentages. Three bare sediment settings (black) as reference.*

- Both Xanthan Gum and Carrageenan increase cohesion.
- Xanthan Gum increases cohesion gradually.
- Carrageenan increases cohesion suddenly, (in range 0.050 – 0.100).
- EPS very sensitive to time.
- High percentages of EPS generates more irregular shaped banks as well as more undercutting.

*Fig. 6: Dried, solid block of sediment with high quantity EPS (XG).*

## Surrogate vegetation

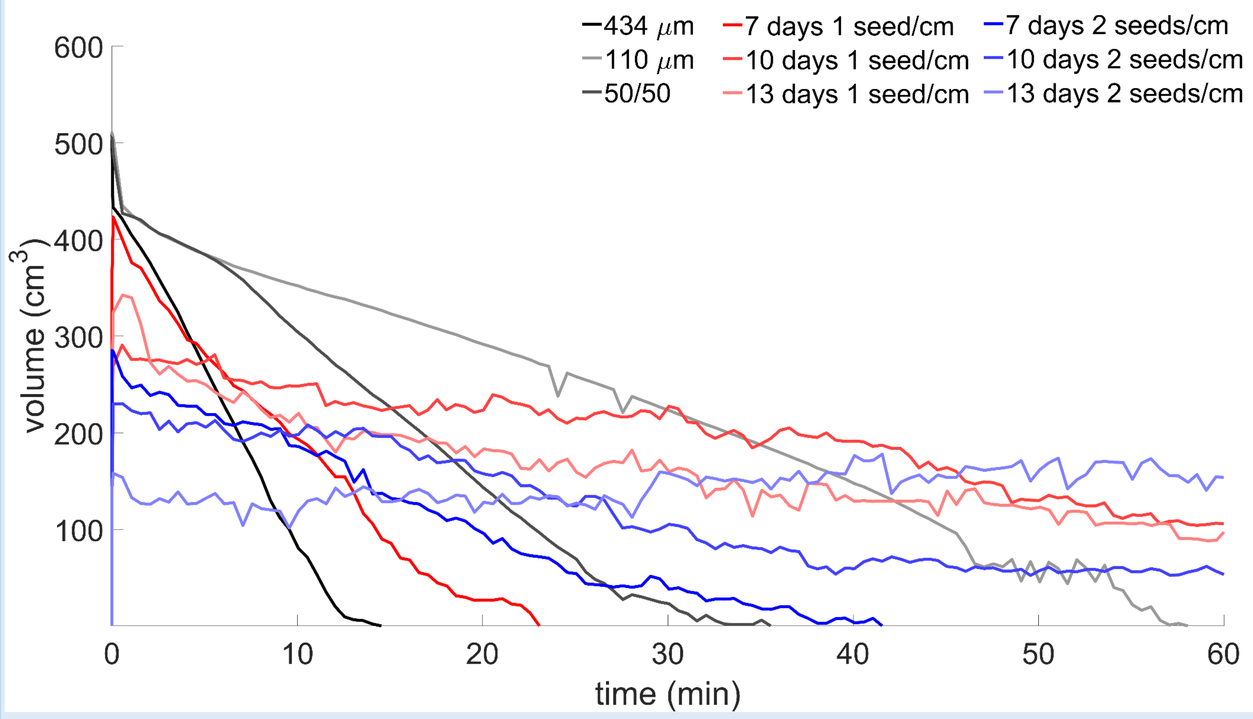



*Fig. 7: Averaged block volume over time with alfalfa vegetation, for low (blue) and high (red) seed density for different ages of vegetation. Three bare sediment settings (black) as reference.*

- Increased seed density increases cohesion.
- More mature vegetation increases cohesion.
- Root structure increases over time (fig 9).
- Eroded vegetation deposits at bank toe and shelters bank from further erosion.

*Fig. 8: Eroded vegetation generating protection for downstream bank.*

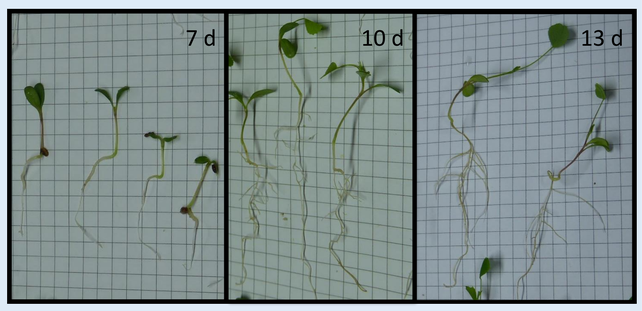



*Fig. 9: Different root structures for 7, 10 and 13 day old alfalfa vegetation.*

## Comparison

- Variability between runs is greater for vegetated runs compared to EPS runs. Variability is lowest in bare sediment runs. (fig 11).
- Both EPS and vegetation can make the block un-erodible.

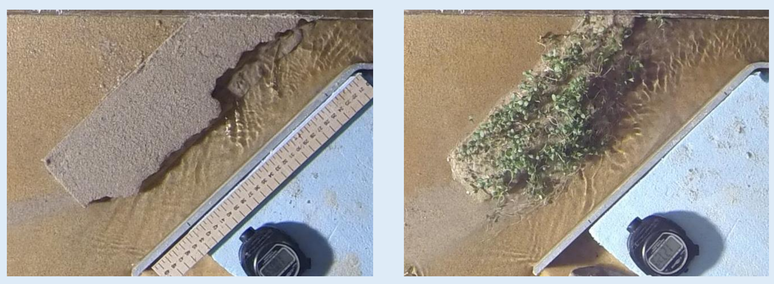


*Fig. 10: A time step in experiment with XG (left) and alfalfa (right).*

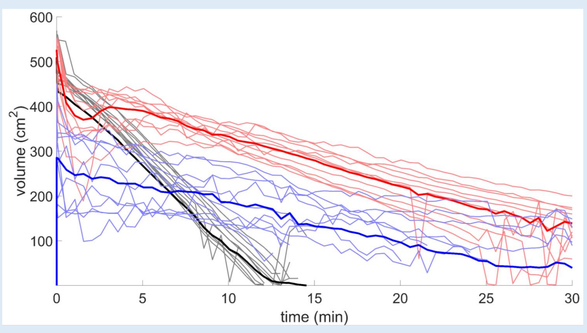



*Fig. 11: Spread of different runs for bare (black), EPS (red) and vegetation (blue).*

- Vegetation is both able to increase cohesion and eroded plants can protect the bank from the flow, EPS is only able to reproduce the effect of cohesion.
- Vegetation causes ponding of water upstream when vegetation is deposited further downstream.
- Erosion with vegetated blocks slows down over time, similar to high densities of CG, but not to XG for which the rate of erosion is less variable.

| Added dry weight % EPS | Carrageenan (CG) | Xanthan Gum (XG) |
|---|---|---|
| 0.0125 | 10 x | 10 x |
| 0.0250 | 10 x | 10 x |
| 0.0500 | 10 x | 10 x |
| 0.0750 | 10 x | |
| 0.1000 | 10 x | 10 x |

*Table 1: Overview settings and replicates experimental runs with EPS.*

| Age | 1 seed / cm² | 2 seed / cm² |
|---|---|---|
| 7 days | 10 x | 10 x |
| 10 days | 10 x | 10 x |
| 13 days | 6 x | 5 x |

*Table 2: Overview settings and replicates experimental runs with vegetation.*

## Conclusion

- Vegetation and EPS are both successful in increasing cohesion of the sediment.
- Xanthan Gum increase cohesion gradually, Carrageenan increases cohesion more abruptly.
- Vegetation age is more effective then seed density in reducing erosion rates.
- Vegetation reduces erosion through both cohesion and by eroded plants protecting the bank from further erosion.
- Xanthan Gum is more controllable, but the behaviour of Carrageenan is more similar to natural vegetation.

## Future Work

- Braided river experiments in 10 m long flume.
- Vegetation allowed to establish and interact with the braided river system.
- Replicate vegetation effects with EPS.
- A range of flood event sequences will be applied to explore the relationship between flood frequency and vegetation establishment and recovery, and consequences for braided river development.


*Fig. 12: Screen capture of earlier experiments on braided rivers in Total Environment Simulator*

## Acknowledgements

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