Scaling Vegetation in Experimental Channel Patterns

Dimitri M. O. van Breemen[1], Wietse I. van de Lageweg[2], Wout M. van Dijk, Maarten G. Kleinhans

Universiteit Utrecht

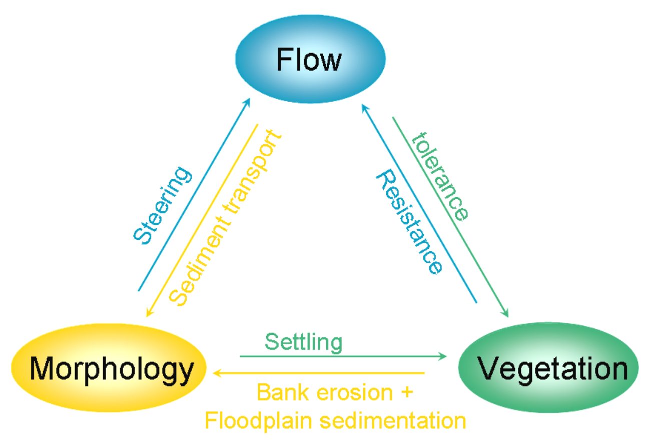
Research group
River and delta morphodynamics


1.


2.

Introduction

Strong feedbacks exist between river channels, floodplains and riparian floodplain vegetation. In these experiments the effects of vegetation on channel pattern are studied. Linear bar theory shows dependency of channel width-depth ratio on bar pattern. Floodplain vegetation adds hydraulic resistance so flow is more concentrated in channels, thus channel width-depth ratio is altered.



The morphodynamic system, updated with the interaction of vegetation with flow and morphology

Objectives

- Develop scalable methods to reproduce vegetation effects in self-formed channels
- Experimentally determine effects of riparian vegetation on bank strength, channel pattern and meandering dynamics

Methods

- pF-curve test: quantify bank strength through matric suction force
- Growth experiments: study growth of vegetation under varying conditions and seed densities. Seed densities are extrapolated to Friedkin and flume experiments
- Friedkin: bank erosion quantification of bare and vegetated substrates
- Flume experiments: synthesis of the aforementioned experiments and analysis and evaluation of channel pattern development

Substrates

Poorly sorted sand (D_{50} = 510 µm) and silica flour (D_{50} = 32 µm) are used for all experiments.

pF-curve test

In order to measure matric suction forces inside pores, 10 control samples of poorly sorted sand and 10 samples with a volume percentage of silica flour ranging between 20 and 35 are selected. Volumetric water content is computed via subtraction of wet and dry sample weight.

pF-curve samples (fixed volume of 100 ml) of poorly sorted sand and a sand-silica flour mixture. Samples are bathed before they are saturated.

Vegetation growth experiments

Three species of model vegetation are put to the test in growth experiments: Alfalfa *(Medigaco sativa)*, rucola *(Eruca sativa)* and thale cress *(Arabidopsis thaliana)*. The following parameters are varied in order to manipulate plant growth:

- Light intensity: Dark and lamps suspended either 60 cm or 250 cm above the vegetation.
- Substrate saturation: saturated pores and a vadose zone
- Seed density: quantified by seed weight with a low (1 g) and high scenario (0.1 g).
- Nutrients: variation of the elements N, P, and K in the substrate. Artificial fertilizer is used in a normal dosage, 10 times and 50 times normal dosage.

a. Pots are shown with the normal dosage of fertilizer, after 8 days of growth. b. Pots are shown with a fertilizer dosage of 50 times normal, after 16 days of growth. c. Default light intensity, flourescent lamps suspended at 250 cm above the sprouts. The right hand container contains pots with vadose substrates. Inside each container the high seed density pots are on the left hand side.

Friedkin erosion tests

Erosion tests are performed using an experimental setup inspired by the work of Friedkin (1945). Constant water discharge attacks the block at a 45 angle and photographs are taken at predefined intervals (often 1 minute).

Friedkin experimental setup showing the erosion of a block of sediment with a high density of rucola sprouts after 0, 40 and 70 minutes.

Flume experiments

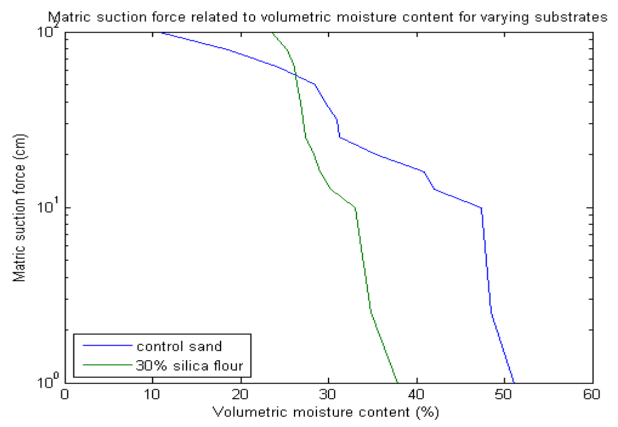
Synthesis of all the abovementioned experiments takes place in a 1.25 m x 7.5 m pilot flume. Photos are taken every 10 minutes to monitor channel pattern evolution. The following parameters are measured hourly:

- Bankfull discharge: 0.3 L/s
- Flow velocity: 0.37 m/s
- Active channel width: bare soil 20 cm, vegetated floodplain 4 cm
- Bar wave length (comparison with predictions from linear bar theory): 2 m

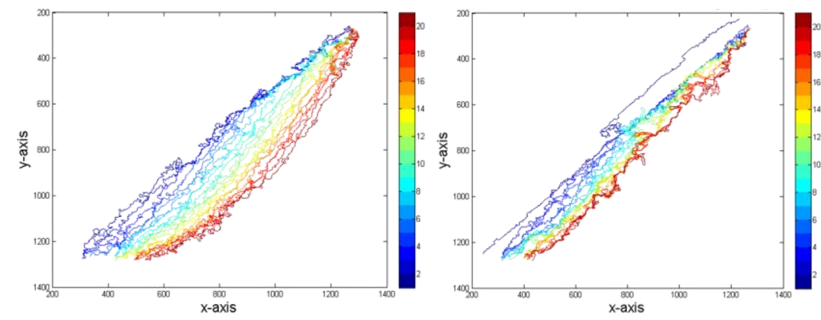
Flume during a bankfull discharge run with a high density of rucola sprouts. Left-handside picture shows initial straight channel, right-handside (looking upstream) shows early stages of morphological development.

Results

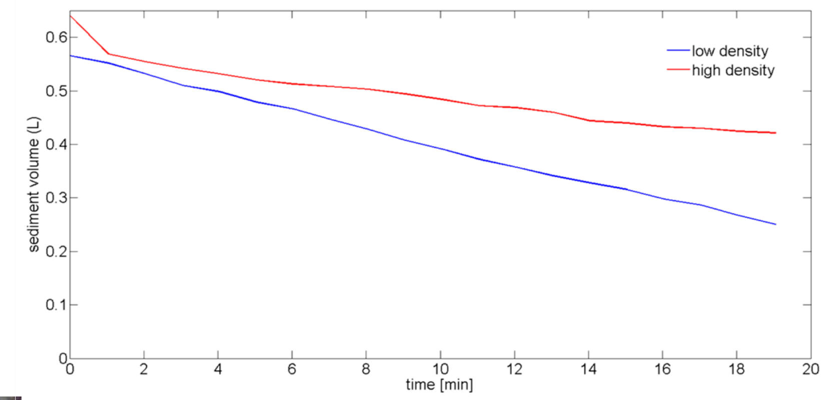
- Effects of silica flour addition are visible as water retention capacities of the substrate are relatively high compared to the poorly sorted sand.
- The silica flour mixture exhibits larger capillary forces inside pores enhancing bank strength and bank cohesion.

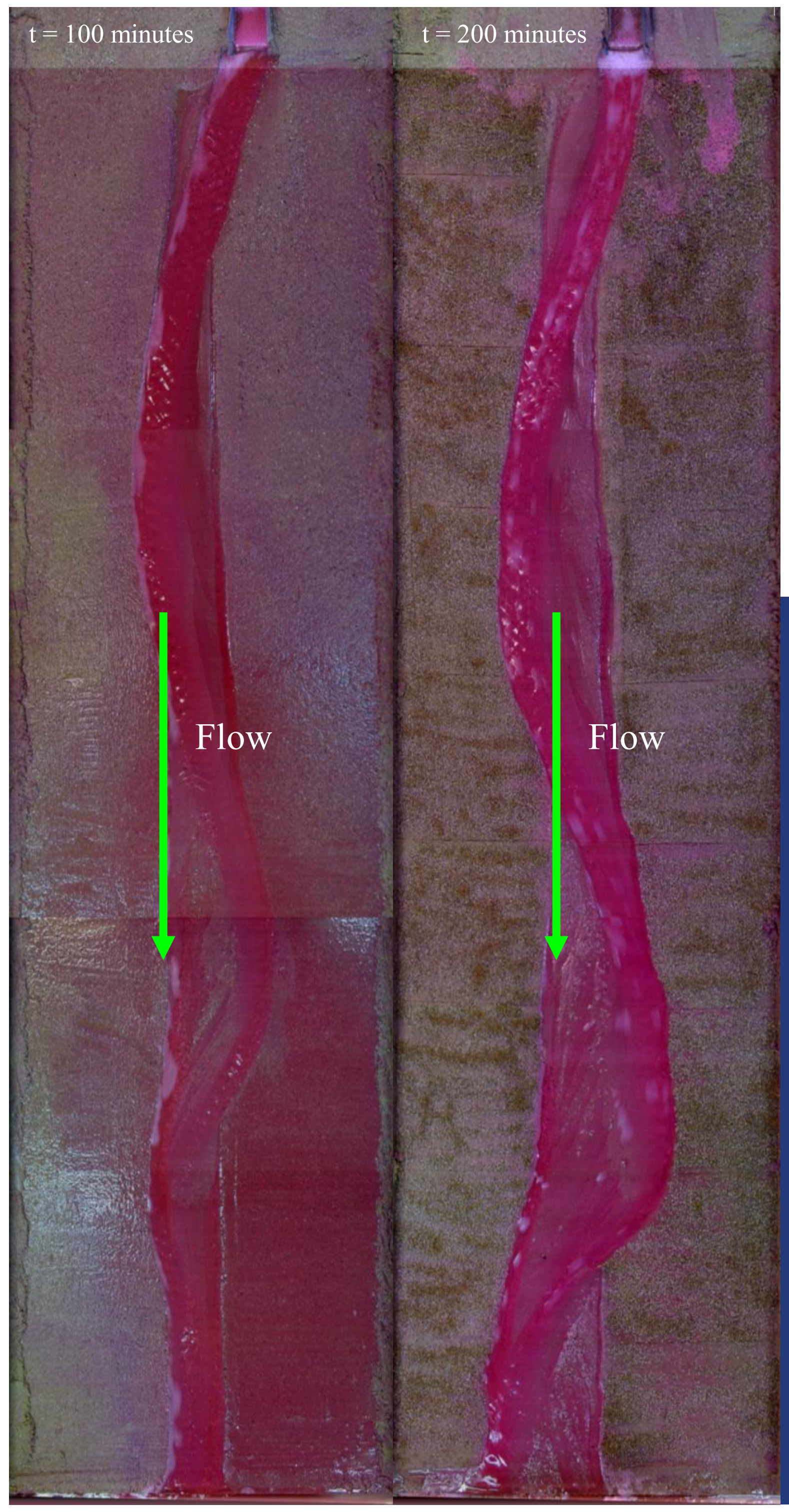


- Banklines of Friedkin sediment blocks are given for the first 20 minutes of run time. This figure shows the bankline degration for a low density vegetation bank (left) and high density vegetation (right) bank.



- Decrease in sediment block volume depends on the sprout density, as the gradient of volume decrease over time is lower for high sprout densities.





- The left hand picture shows a bare soil run, the right hand picture shows a high density vegetated run.
- Outer bank erosion decreases due to the presence of riparian vegetation.
- Rate of lateral migration and scroll bar formation decreases due to an increase in hydraulic resistance and bank strength.

Conclusions

- Silica flour serves as a surrogate for clay, as it exhibits similar water retention capacities
- High light intensity, a high seeding density and addition of the proscribed dosage of artificial fertilizers are beneficial for plant growth.
- Both the Friedkin erosion tests and flume experiments show reduced erosion rates with increasing vegetation density.