Interactions between braiding and vegetation leading to the formation of single-thread channels: results and insights from laboratory experiments
Effects of vegetation on channel morphology

- Braiding
  - Tasman River, New Zealand

- Meandering
  - Fly River, Papua New Guinea
Impacts of vegetation at local scales

Roughness

Channel narrowing

Root binding
Impacts of vegetation at local scales

Sediment deposition and formation of proto-islands

Flow obstruction

Ain R., France

Bank protection
Impacts of vegetation on local scales

Bank protection

Ain R., France

“lopping and layering”
Motueka R., NZ
Impacts of vegetation at the reach scale

Platte River, central Nebraska

Late 1800s

Present
Impacts of vegetation at the reach scale

Platte River near Kearney, Nebraska

Vegetation is the gray

1938

1957

1979

Eschner et al., USGS report, 1983

October 1938

August 1998
Impacts of vegetation at the reach scale
Isolating the effects of vegetation

\[ w = aQ^b \]

Leopold & Maddock (1953)

Tal et al, 2004
The “ratchet” effect
Experimental meandering channels

(Friedkin, 1945)

(Smith, 1998)
Numerical models of channel patterns

Cellular Braiding Model (Murray & Paola, 1994; Murray & Paola, 1997)

- Fully developed meandering cannot develop without some form of bank stabilization to constrain the flow laterally
- Braiding represents the default condition for rivers in non-cohesive sediment
Laboratory experiments with vegetation, SAFL

Gran & Paola, *WRR* (2001)

**Braiding index**

**Width/depth**

**Lateral mobility of channels**

**Braiding index**

**Width/depth**

**Lateral mobility of channels**

unvegetated

high-density vegetation

Gran & Paola, *WRR* (2001)
Laboratory experiments, SAFL

Dynamic Interactions

High flow (2.0 x 10^{-3} \text{ m}^{3}/\text{s}): transports sediment, reworks morphology
Low flow (4.0 x 10^{-4} \text{ m}^{3}/\text{s}): seedling establishment and growth
Experimental facility, SAFL

D50 = 0.5 mm, transported as bedload

Sediment feeder

Sediment box traps
Experimental facility, SAFL

Dye-intensity for estimating flow depth

Laser line for bed-topography
Scaling
Alfalfa (Medicago sativa)

Length scale ratio (model/field) = 0.0125

Flow
Average Froude numbers: 0.3 – 0.8
Average Reynolds numbers: 10500 - 22500

Sediment
$D_{50} = 0.5 \text{ mm model} \sim 40 \text{ mm field}$

Alfalfa densities of 9 stems/cm² add root cohesion of 11.6 kPa to sand with 0 kPa cohesion (Pollen and Simon, 2006)
Interactions between riparian vegetation and braiding leading to the formation of single-thread channels

Planform change
- Decrease in wetted width
- Decrease in width/depth
- Decrease in number of channels
- Increase in sinuosity

Self-organization
- Dynamically maintained single-thread channels
- Bankfull geometry
- Floodplain formation

Towards a physically based model of channel migration in meandering streams

Gary Parker, Univ. of Illinois
Yasuyuki Shimizu, Kensuke Kobayashi, Univ. of Hokkaido, Japan

Model assumptions: Ikeda, Parker & Sawai (1981):
• Outer bank erodes at a rate proportional to $\Delta u$
• Inner bank deposits at whatever rate is necessary to keep up with the outer bank
• Width remains constant

How does it know???
Inside bank to outside bank:

“Yes, I’m following you.”
Inside bank to outside bank:

“Yes, I’m following you.”
Outside bank to inside bank:

“Yeah, while you were pretending to listen, look at the mess we got ourselves into!”
Towards a physically based model of channel migration in meandering streams

Net imbalance between erosion and deposition due to the processes of shaving and extension approaches 20%
Maintaining constant channel width

Cut bank erosion slowed down by **vegetal armoring** and deposition driven and reinforced by vegetal trapping help maintain a roughly constant width as the channel migrates.

“If I’m going to talk to the inner bank, I need something to slow me down”

“If I’m going to talk to the outer bank, I need something to speed me up”
Increased bank stability leading to slower rates of bank erosion

Channel cutoffs

Vegetation leads to wholesale diversion of the flow and discourages the coexistence of multiple channels

In contrast with the braided system, where channel switching is a nearly continuous process with persistent flow shifting among multiple channels following slight gradient differences, the vegetated state produced **less frequent** but **more distinct avulsions**.

Incoherent versus coherent change

T1

T2
Unvegetated, braided

T2 – T1

T1

T2
Vegetated, single-thread

T2 – T1

At bankfull flow the river is on the verge of spilling out onto its floodplain.

Channel bankfull geometries

often reasonably estimated in terms of a peak flood discharge with a recurrence interval of 1-2 years.
Braided to bankfull geometry

Paola et al. (1999)
### Transition matrices

**class 1** - bare, sparse  
**class 2** - medium density  
**class 3** - very dense

<table>
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<th>Wet</th>
<th>Dry</th>
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<tbody>
<tr>
<td>Flow</td>
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Flow localization leading to a reduction in wetted width

Activités de recherche : influence de la végétation sur les rivières alluviales

Transition vers un chenal unique

Largeur totale des chenaux

Haut débit

Bas débit

densité de la végétation

Nombre de crues

Largeur totale des chenaux (mm)
Steady-state

Plant growth time (days)

Vegetated area as a fraction of total area

Flow localization leading to stronger channels capable of fighting back

Connectivity of zones of high unit discharge

Bankfull Geometry:

- bars growing to the full height of the flow
- excess channel area at low flow gets occupied by the plants
- vegetation has the ability to block overland flow while allowing bank erosion

No undersized or oversized channels
Formation of floodplains
Summary

• Vegetation that is well established is more difficult to remove than young and weak vegetation.

• Plants alone are able to achieve the two key mechanisms to developing meandering: slowing the rate of widening and discouraging channel cutoffs.

• Vegetation introduces a threshold for cutoffs and avulsions that results in wholesale diversion of the flow and discourages the coexistence of multiple channels.

• The ability of the plants to deter the high flow from reoccupying abandoned areas at the low flow leads to progressive reinforcement of the low flow wetted width and elimination of unutilized space.

• Fluctuating discharge is key to promoting the transition from braiding to single-thread.

• Plants cause the system to organize into a distinct channel and non-channel area. The non-channel area is composed of previously active parts of the braidplain that become vegetated and gradually merge to create a well defined floodplain.
Women in Geosciences: past and present

19th century
La Sorbonne, Paris