Quantifying the impact of blanket-peat re-vegetation & gully-blocking in terms of their NFM potential

Webinar Series

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Content

• Before-After-Control-Intervention (BACI) experiment
• Findings of the BACI experiment
• Motivations of the numerical work
• Brief introduction of numerical procedure
• Numerical experiment #1: Impact of restorations, and their variation with storm size
• Numerical experiment #2: Underlying processes, and their variation with storm size
• Does NFM always work?
• Conclusions & Future Work
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Location of study sites

Bare peat

Deep gully
BACI Experiment

**CR:** control site  
**RV:** re-vegetated site  
**RG:** re-vegetated & gully-blocked site  

- **Outlet**  
- **Block location**

*For comparison: a standard football pitch is 7,140 m²*

*all satellite images are recent (2020)*
Rapid restoration success

stone dams
2010
re-vegetation
2014
timber dams

2011
re-vegetation &
gully-blocking
2018
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BACI Observations

*Data extracted from Shuttleworth et al. (2019)
**all values relative to control site

Relative OFQ = portion of dipwell tubes recording overland flow, relative to control site
BACI Observations

**Data extracted from Shuttleworth et al. (2019)**

***all values relative to control site***

Relative peaks post treatment

Relative lags post treatment

**Data extracted from Shuttleworth et al. (2019)**

***all values relative to control site***
Surface Storage

<table>
<thead>
<tr>
<th>Static (immobile) surface storage</th>
<th>Dynamic (mobile) surface storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interception storage</td>
<td>“flow storage”</td>
</tr>
<tr>
<td>Block storage</td>
<td></td>
</tr>
</tbody>
</table>

- Smoother surface = faster flow
- Faster flow = less accumulation
- Rougher surface = slower flow
- Slower flow = more accumulation
BACI Observations

Data extracted from Shuttleworth et al. (2019)
**all values relative to control site
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Summary of knowns

• Water tables rise
• Hillslope storage is reduced
• Overland flow production is enhanced
• Lags increase and peaks reduce
• Dynamic storage is more important
• Roughness is more important
• Gully-blocking impact is significant

Questions to answer

• Is dynamic storage always more important?
• How much more important is dynamic storage?
• What about evapotranspiration?
• Do these findings hold for all storm sizes?
• Potential importance of different sources of uncertainty: rainfall, topography
• Are there situations where NFM won’t work?
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Schematic of the numerical procedure

- **Period X**
  - **re-veg. site (RV)**
  - **blocked site (RG)**

**Numerical Model (TOPMODEL)**

**Calibrate**

**RV site:**
- Dynamic surface storage
- Evapo-transpiration rate
- Static surface storage

**RG site:**
- Dynamic surface storage
- Evapo-transpiration rate
- Static surface storage
Pre-intervention period (2010)
Post-intervention period (2012)

- control (CR)
- reveg. (RV)
- reveg&blocked (RG)
- rainfall
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Numerical experiment #1: “Virtual Twin”

- Fix topography
- Fix rainfall

Numerical Model (TOPMODEL)

- pre-RV parameters
- post-RV parameters
- pre-RG parameters
- post-RG parameters

predict discharge & compare

discharge
Numerical experiment #1: “Virtual Twin”

Largest storms ➡️

Most complex storm ➡️

RV: re-vegetated site
RG: re-veg. & gully-blocked
Variation with storm size

Across all 20 peaks, mean discharge reduction due to:
- revegetation was 34%
- revegetation & gully blocking was 43%

Across all 20 peaks, mean of lag-time increase due to:
- revegetation was 0.62 hr
- revegetation & gully blocking was 0.8 hr
Comparison with observations

**Modelled**

- re-veg
- re-veg & blocked
- modelled

**Not modelled**

*1% = 5.3 Lit s⁻¹ km⁻²*
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Numerical experiment #2: “Parameter Switch”

Fix topography

Fix rainfall

Numerical Model (TOPMODEL)

re-vegetated site (RV)
all parameters, except one, at pre-treatment value

predict discharge & compare

re-veg. & blocked site (RG)
all parameters, except one, at pre-treatment value

Evapo-transpiration
Parameter shares in peak reduction

- re-veg. (RV)
- re-veg. & blocked (RG)

**Graphs:**
- x-axis: Peak Discharge [m³/s]
- y-axis: Share of discharge change [%]
- Colors represent different parameters:
  - Velocity (dynamic storage)
  - Evapotranspiration
  - Static storage

**Legend:**
- post-RV
- post-RG
- pre-RV
- pre-RG
Parameter shares in lag increase

- re-veg. (RV)
- re-veg. & blocked (RG)

Graphs showing the share of timing change [%] against peak discharge [m³/s] for velocity (dynamic storage), evapotranspiration, and static storage. The graphs compare data before (pre-RV, pre-RG) and after (post-RV, post-RG) re-vegetation and blocking events.
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Does NFM always work?

(a) RV: re-veg.
RG: re-veg. & blocked

(b) obs Q
pre-RV
post-RV
pre-RG
post-RG
rain

Discharge [m³/s]

Time [hrs] since 1st October 2010

Rainfall [mm]

Discharge [m³/s]

Time [hrs] since 3rd October 2010
Duration of peak rainfall intensity

peak #1

peak #3

Oct 01

Oct 03

Rainfall [mm]

Discharge [m3/s]

0
0.5
1
1.5
0
0.005
0.01
0.015
0
0
0
0
10:00 10:30 11:00 11:30 12:00 12:30 13:00

07:00 07:30 08:00 08:30 09:00 09:30 10:00

10 min

70 min

[Legend]

- rain
- obs Q
- pre-RV
- post-RV
- pre-RG
- post-RG
Conclusions

- Modelling supports the BACI findings that peaks are reduced and lags increased by re-vegetation and gully-blocking.
- Roughness, both due to re-vegetation and gully-blocking, introduces dynamic (mobile) surface storage that is:
  
  1. the most important delivery mechanism for the observed intervention impacts
  2. independent of storm size
- Storm properties can strongly alter the discharge reduction of interventions, although not their lag increase.
Future work

- Depth dependent surface velocity
- What happens when you scale up?
- How do the intervention effects change over time?