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Artificial surfaces characteristics and sediment connectivity explain muddy flood hazard in Wallonia

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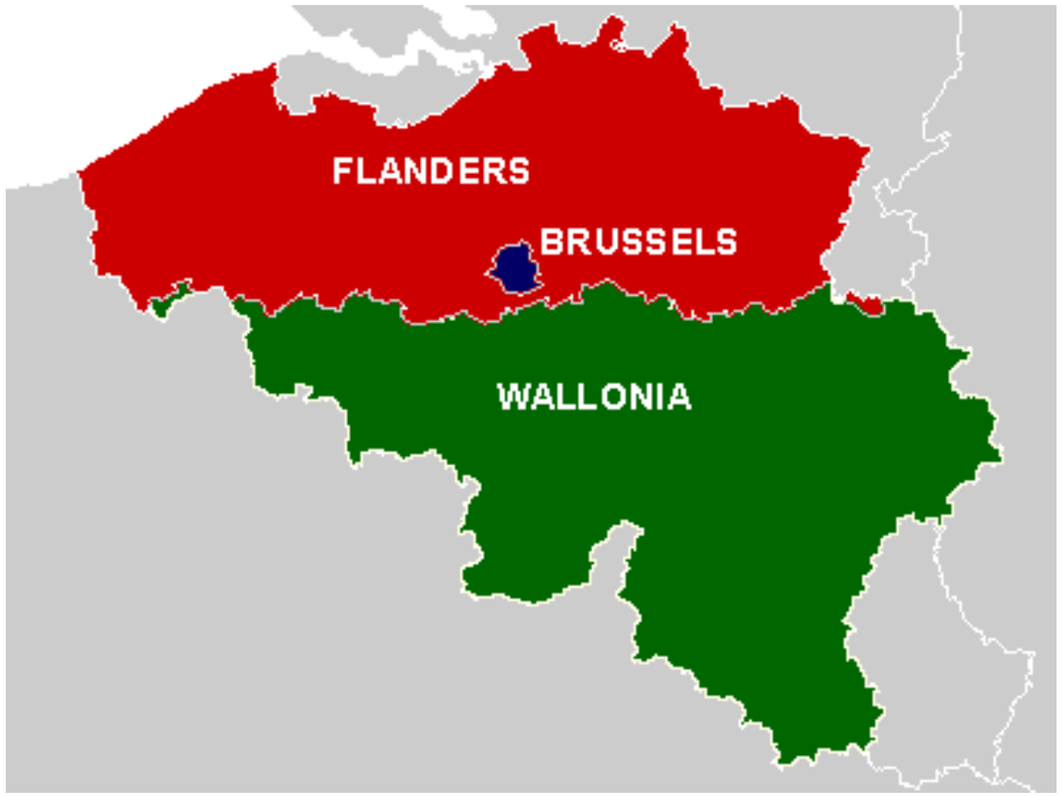
The muddy flood hazard in Wallonia



Map of regions of Belgium.

Source: https://www.brusselsjournal.com/node/2433

Examples of muddy flood cases between 2011 and 2015.

The muddy flood hazard in Wallonia

- Over a 10-year period, 27% of the municipalities in Wallonia were confronted with muddy floods at least once every two years (Bielders et al., 2003).

- For central Belgium, resulting financial costs range between 12.5 and 122 million € yr^{-1} depending on the year (Evrard et al., 2007).

- Psychological stress to people regularly exposed.

➔ Need to better understand the causal factors and to develop a tool for identifying sites at risk of muddy floods

Objectives of the study

- Develop a reliable tool to assess the muddy flood hazard at any location in Wallonia.
- Quantify the contribution of various intrinsic watershed characteristics to muddy flood hazard.
- Evaluate whether the inclusion of a sediment connectivity index improves the performance of the model developed.

General approach

Database of 490 muddy flood affected sites (MFS) (2009-2016).

No information about the date of occurrence or frequency of muddy floods at these sites.

A paired watershed approach was used: For each MFS, a non-flooded site (NFS) was selected following 3 criteria:

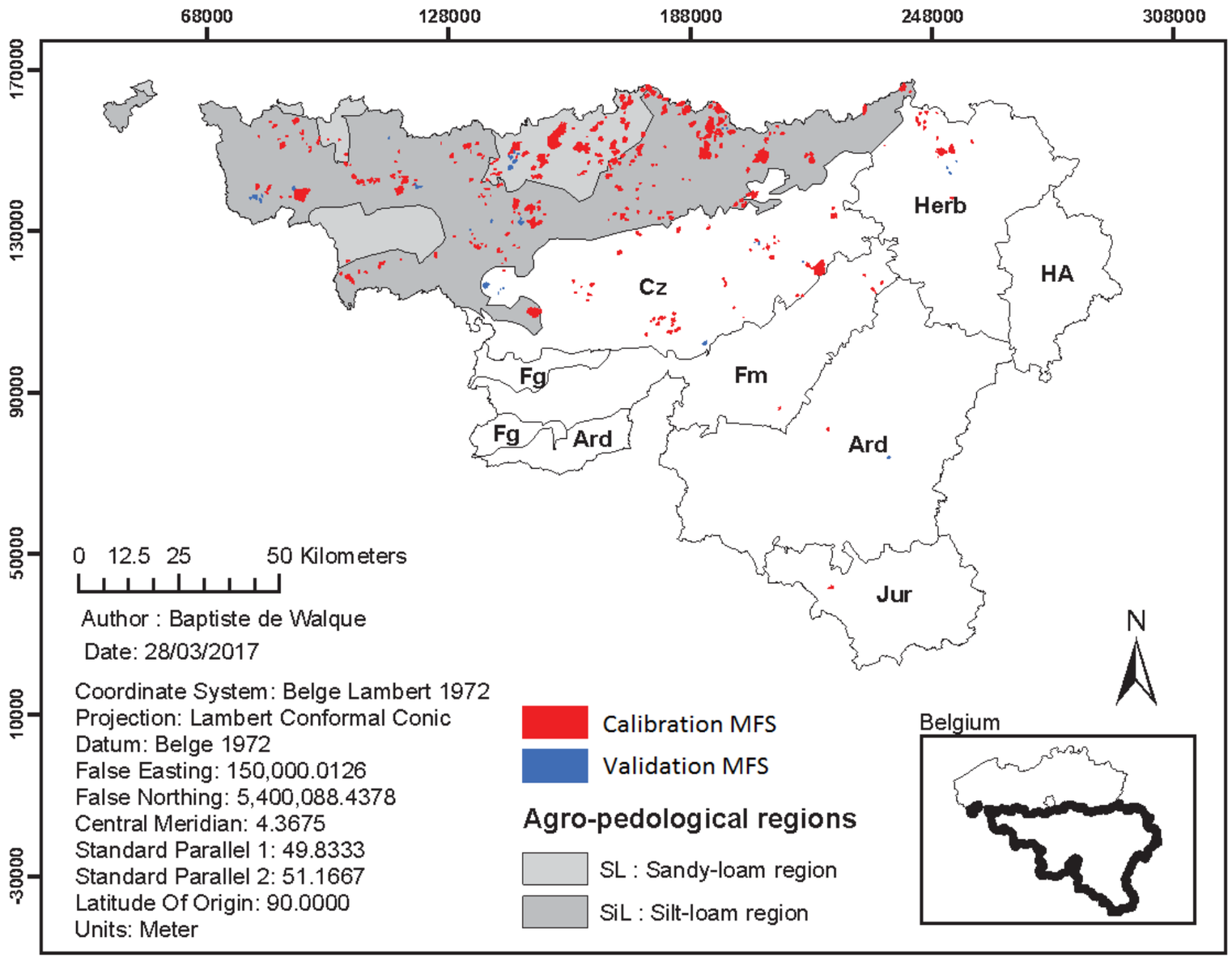
a) Similar contributing areas of MFS and NFS

b) High proportion of artificial surfaces close to the outlet as possible (high potential vulnerability)

c) NFS as close to the MFS as possible

Logistic regression model of muddy flood hazard using watershed characteristics as independent variables

Calibration and validation datasets



MFS:
- Calibration: 442 sites
- Validation: 48 sites

Fig. 1 : Map of agro-pedological regions and muddy flood-affected sites (MFS). Source : Ministère des classes moyennes et de l'agriculture.

Indices tested in logistic regressions

(Characteristics of contributing area)

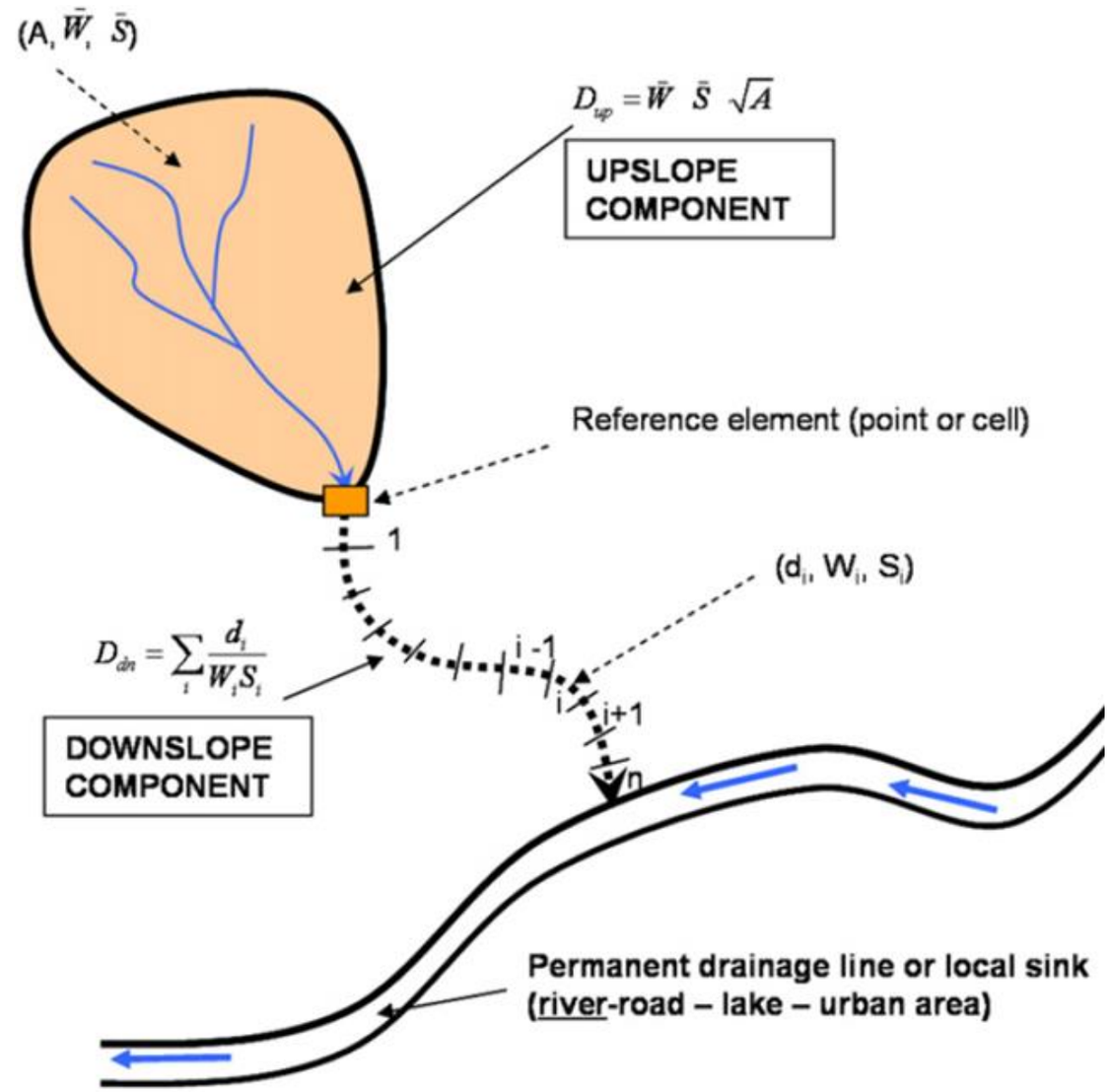
Geomorphological parameters	→	Mean slope
	→	Gravelius shape index
Land use parameters	→	Proportion of cropland, artificial surfaces, permanent pastures and forests
	→	Mean proximity to outlet of artificial surfaces
	→	Artificial surfaces aggregation
Sediment transport related variables	→	Sediment production (RUSLE)
	→	Sediment connectivity index (Borselli) [mean and percentiles]
	→	Revised sediment connectivity index [mean and percentiles]

The sediment connectivity index of Borselli

Original formulation

$$IC_k = \log_{10} \frac{D_{up,k}}{D_{dn,k}}$$

$$= \log_{10} \frac{\bar{W}_k \bar{S}_k \sqrt{A_k}}{\sum_{i=k,n_k} \frac{d_i}{W_i S_i}}$$



Source: Borselli et al., 2008

Revised formulation

$$IC_{k,new} = \log_{10} \frac{\left(\sum_i R_i \times K_i \times LS_i \times C_i \times S_{pixel}\right)_k}{\left(\sum_j \frac{n_j d_j}{S_j}\right)_k}$$

Best multiple logistic regression

$$Hazard = \frac{1}{1 + e^{(\alpha + \sum_{i=1}^{n} \beta_i X_i)}}$$

Coefficient		Coefficient value	p-values
α (intercept)		-0.583	
β	Mean slope	-13.254	$9.49\ 10^{-4}$
	Gravelius shape index	Not retained	
	%Cropland	Not retained	
	%Artificial surfaces	-0.029	$1.29\ 10^{-5}$
	%Permanent pastures	Not retained	
	%Permanent forests	Not retained	
	Artif. surf. mean proximity to outlet	3.687	$3.23\ 10^{-11}$
	Artif. surf. aggregation	-0.023	$5.30\ 10^{-5}$
	99th perc. revised IC Borselli	1.193	$2.22\ 10^{-12}$

Model prediction quality

1) **Calibration** on 442 pairs of sites :
   76% well classified

2) **Validation** on 48 pairs of sites :
   81% well classified

Conclusions

- The most important variables were related to sediment connectivity and artificial surfaces characteristics in the contributing area.
- The proposed revised version slightly outperformed the original Borselli index in our model.
- A statistical muddy flood hazard model for Wallonia, Belgium was developed and showed good prediction qualities

  → Prioritization of sites for implanting mitigation measures

Thank you for your attention

Baptiste de Walque, Aurore Degré, Alexandre Maugnard, Charles L. Bielders. Artificial surfaces characteristics and sediment connectivity explain muddy flood hazard in Wallonia. Catena, under review.