

A scale-independent cost-effective design of Nature-Based Solutions within a multifractal framework

Yangzi Qiu¹, Daniel Schertzer¹, Ioulia Tchiguirinskaia¹, Laurent Monier², Bernard Willinger³, and Bruno Tisserand⁴

¹ Ecole des Ponts ParisTech, HM&Co, Champs-sur-Marne, France

² BSP, Veolia, 30 rue Madeleine Vionnet, 93300 Aubervilliers, France

³ Veolia Eau, 2 rue du buisson aux fraises, 91300 Massy, France

⁴ Veolia Research and Innovation, Chemin de la Digue, 78600 Maisons-Laffitte, France

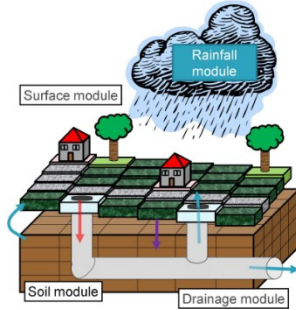
Context

- Nature-Based Solutions (NBS): a sustainable development strategy for the development of urban environments.
- Hydrological performances integrated with Life-cycle costs.
- Universal Multifractal framework (Schertzer and Lovejoy, 1987).

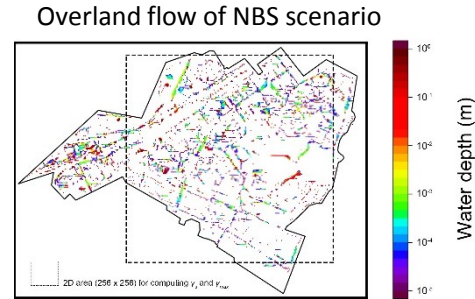
Designing scale-independent cost-effectiveness (CE) NBS scenarios

Materials and Methods

Multi-Hydro: Modelling of hydrological performances of NBS scenarios



Output of Multi-Hydro: overland flow maps of NBS scenarios



Universal Multifractals

The statistics of a highly intermittent field, ε_λ , is described by its probability:

$$Pr(\varepsilon_\lambda \geq \lambda^\gamma) \approx \lambda^{-c(\gamma)}$$

UM parameters

Mean intermittency C_1 , which measures the average sparseness of the field.

Multifractality index α ($0 \leq \alpha \leq 2$), describes the degree of multifractality of the process.

- Scale-independent indicator of **maximum probable singularity γ_s**

$$\gamma_s = \frac{\alpha}{\alpha - 1} C_1 \left(\frac{D}{C_1} \right)^{\frac{\alpha - 1}{\alpha}} - \frac{C_1}{\alpha - 1}$$

where α and C_1 are the UM parameters, and D is the dimension of the field.

- Scale-dependent indicator of **effective maximum singularity γ_{max}**

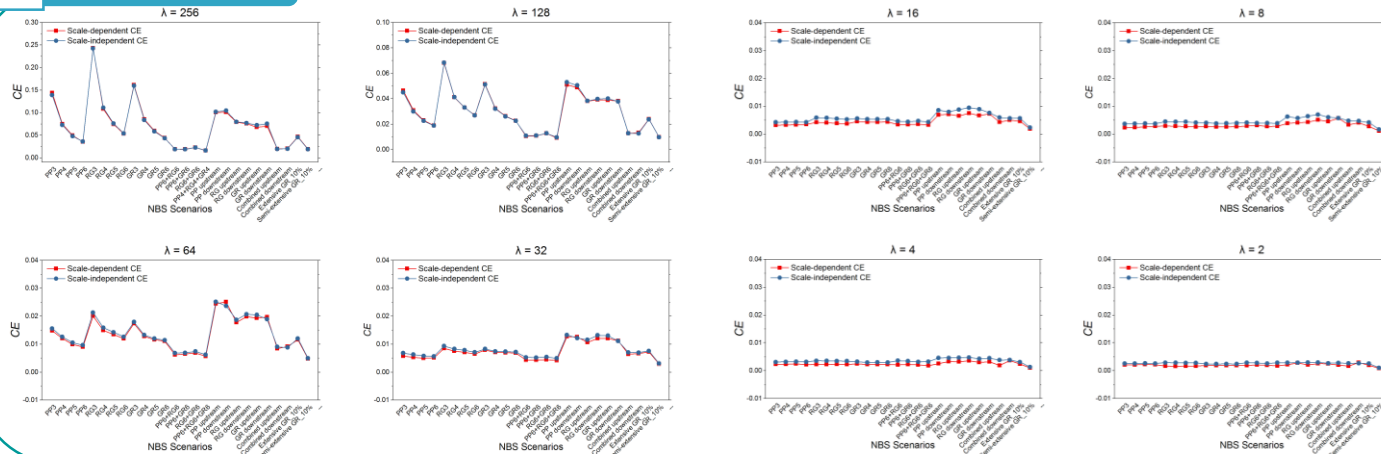
$$\gamma_{max}(t) = \log_\Lambda \left(\frac{H_{max}(t)}{H_{mean}(t)} \right)$$

where $H_{max}(t)$ and $H_{mean}(t)$ is the maximum value and mean value of overland flow at time t , respectively; Λ is the largest resolution.

Economic indicator: Life-cycle costs

Scale-independent cost-effectiveness (SICE) indicator

Results



Conclusions and Perspectives

- The cost-effective NBS scenarios change with changing the scale.
- At the small scale range, the most cost-effective scenario is Rain garden 3 scenario.
- At the large scale range, the NBS downstream scenarios are more cost-effective than the other NBS scenarios.
- ◆ This method is so general that can be easily applied in some other catchments and support decision-making process.

Reference:

Schertzer, D., & Lovejoy, S. (1987). Physical modeling and analysis of rain and clouds by anisotropic scaling multiplicative processes. Journal of Geophysical Research, 92(D8), 9693–9714.