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

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In the last decades, Nature-Based Solutions (NBS) have become widely considered as a sustainable development strategy for the development of urban environments. Many previous studies only focused on the hydrological performances of NBS, whose economic impacts were not considered. Some studies considered both hydrological performances and economic costs to design cost-effective NBS scenarios, but only at a single catchment scale. Thus, a comprehensive investigation of NBS in terms of both hydrological performances and Life cycle costs (LCC) within the Universal Multifractal (UM) framework is significant for improving the multi-scale resilience of cities. In this study, the hydrological response of a 5.2 km$^2$ semi-urban watershed is investigated under various NBS scenarios and highly spatially variable rainfall events. First, the heterogeneous spatial NBS distribution in each scenario is quantified using their fractal dimension. Then, the hydrological responses are assessed with the help of the fully-distributed and physically-based model (Multi-Hydro) with a spatial resolution of 10 m. To evaluate the cost-effectiveness of NBS scenarios across scales, the statistical scale-independent “maximum probable singularity” $\gamma_s$, as defined in the UM framework, is combined with the economic indicator (LCC) to obtain the scale-independent cost-effectiveness (scale-independent CE) indicator for designing cost-effective NBS scenarios. The effective maximum singularity $\gamma_{max}$ of each simulation is combined with LCC at different scales to obtain a scale-dependent cost-effectiveness (scale-dependent CE) indicator to be compared with the scale-independent CE. Results show that CEs obtained by both methods are strongly correlated, especially over the small-scale range. Therefore, the scale-independent CE based on UM framework is considered as an appropriate indicator to design NBS implementation at different scales.

Overall, this study presents a new approach for designing cost-effective NBS scenarios. This approach is based on the UM framework and enables to quantify the NBS scenario cost-effectiveness across a range of scales with the help of a scale-independent CE indicator. This approach can be efficiently applied to urban planning across various scales.