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Hydro-social multi criteria analysis to implement SUDS: from subcatchment delineation to siting solutions

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Highlights:

- Novel methodology applied to hydrologic-hydraulic models, to simplify subcatchment delineation and semi-automatized insertion of SUDS considering land use criteria.
- Prioritization of city-sections based on multi-criteria analysis of hydro-social variables, categorized into two groups: hydrological and social-environmental.

Keywords: SUDS; subcatchment delineation; multi-criteria analysis.

INTRODUCTION

Climate change and urbanization pose significant threats to flooding and water quality in urban areas. Flooding has recently caused numerous problems and the lack of stormwater infrastructure also contributes to the increasing volume of Combined Sewer Overflows (CSO), responsible for 30–95% of the annual load for different pollutants (Botturi et al., 2020). To face this scenario, cities must move away from approaches that encourage only quick water remotion, to deploy sustainable urban drainage solutions (SUDS), which are engineered solutions that mimic biochemical and physical processes found on nature, controlling floods while also improving runoff water quality (Lee et al., 2018). Additionally, SUDS, when nature-based (frequently called nature-based solutions-NbS) can provide ecosystem services (ES), improving environmental conditions linked to positive health outcomes and building community cohesion (Markevych et al., 2017). Therefore, hydraulic-hydrological models, focused on measuring SUDS efficiency, are encouraged to amplify the criteria to define priority locations for siting the green infrastructure, and consequently enhance a greater scope of ES. This amplified range of criteria refers to the hydro-social variables, here understood as aspects that go beyond the dynamics of water flow, being also related to socio-environmental conditions, such as education level, age, financial income, proximity to green areas, new development areas, public spaces, and city growing strategies. Meanwhile, usual methods for modeling green solutions demand substantial time effort for subcatchment discretization to properly represent land properties and baseline conditions (Lee et al., 2018). Therefore, a methodology capable of simplifying the delineation of urban subcatchments, while considering a greater criteria spectrum for siting solutions, and visioning synergies with other governmental urban agendas, should include hydro-social variables to design more efficient urban drainage subsystems (UDS) within Urban Water Systems (UWSs). In summary, the main goal of this work was to develop a simplified methodology, open source based, to build a high spatial resolution hydrologic-hydraulic model to allocate SUDS considering the analysis of hydro-social variables at two spatial scales: (i) at section level, considering hydro-social city needs (hydrological response of the UDS and socio-environmental context); (ii) identification of allotments for siting SUDS at parcels.

METHODOLOGY

The prioritization of sectors and allocation of SUDS at allotments are made through multi-criteria analysis (MCA) of two categories of variables(Arnaud et al., 2024): group one is the hydrological category, which refers to aspects related to the UDS and landscape response to rain events, such as CSOs, pipe surcharge, node flooding, and land parcels' hydrogeological opportunities or constraints; the second group is the socio-environmental category, which encompasses aspects related to ecosystem services (for instance, green service area, density of green areas within the sector and areas serving important ecosystem functions), social vulnerability (financial income, GINI coefficient, among others) and governance assets (including free public spaces, institutional buildings, city growing strategies and other municipal legal framework). The weighting of these criteria is proportional to the importance considered for each one, and can be defined by citizens and/or panels of experts. The proposed methodology integrates various steps executed on top of an existing hydrologic-hydraulic model and employs four open-source software: SWMM (Storm Water Management Model), a plugin dedicated to the integral management of the water cycle, named GISWATER, which communicates SWMM to a Spatial database using the interface of QGIS, and RStudio for georeferencing socio-environmental data. The steps dedicated to endowing topological consistency, model calibration, and hydraulic efficiency evaluation are not our focus. Rather, our aim is to shed light on the process of conducting subcatchment delineation, which streamlines SUDS allocation, guided by MCA. Therefore, the key steps considered in the method include: ***(i)*** Gathering hydro-social data of the UDS and by each city section ***(ii)*** Subcatchment delineation considering the definition of plots with a unique land use, to obtain a representative hydrological response of all elements within each subcatchment; ***(iii)*** Flow routing direction considering surface level gradient and maximum path length (using a QGIS plugin developed by ICRA (Pueyo-Ros, n.d.)); ***(iv)*** Definition of unit areas within a given range per land use type to promote hydrological continuity; ***(v)*** Construction of a SUDS technical catalog with configurations designed for each land use; ***(vi)*** MCA of the socio-environmental data and UDS hydrological response (bottlenecks within the drainage network) aggregated at city-sections to calculate the scores of each section and rank a priority list; ***(vii)*** MCA of hydro-social variables, to identify parcels of land with the greatest potential for implementing SUDS, considering the previous ranking at city-section scale; ***(viii)*** automated insertion of SUDS, based on the land use of each parcel; ***(ix)*** generating scenarios, one with SUDS allocated at public spaces and buildings, and other also considering its placement at private allotments. The latter would augment the city runoff management capability at source (through water cycle restoration at more parcels of land), as well as rain harvesting where allowed, besides inspiring future legislation related to land use and drainage responsibility of property owners. The method is being applied to the city of Girona.

RESULTS AND CONCLUSIONS

So far, we have obtained 65 sections and 2.535 subcatchments (**Figure 01**), and a SUDS catalog composed of permeable pavement, cistern, infiltration trenches, and infiltration-detention basins. The the application of GIS-MCDA enables the integration of environmental, socioeconomical and hydrological information to identify priority areas for implementing in the two spatial scales: section level and the identification of specific allotments for locating SUDS at the parcel level. This two-tiered study has not only pinpointed neighborhoods (seccions) that require greater efforts in renaturalizing drainage but also categorized public spaces and private allotments (such as parkings and large edifications), paving the way for future interventions. The distinctive aspect of this method refers to the possibility of including urban socio-environmental aspects together with the usual hydraulic-hydrological criteria, without adding technical complexity to the process. The method ensures technical suitability while addressing other governance demands through planning drainage infrastructure integrated to other urban strategies. Moreover, the same methodology can be applied on feasibility studies for siting decentralized solutions intended to promote fit-for purpose water reuse.

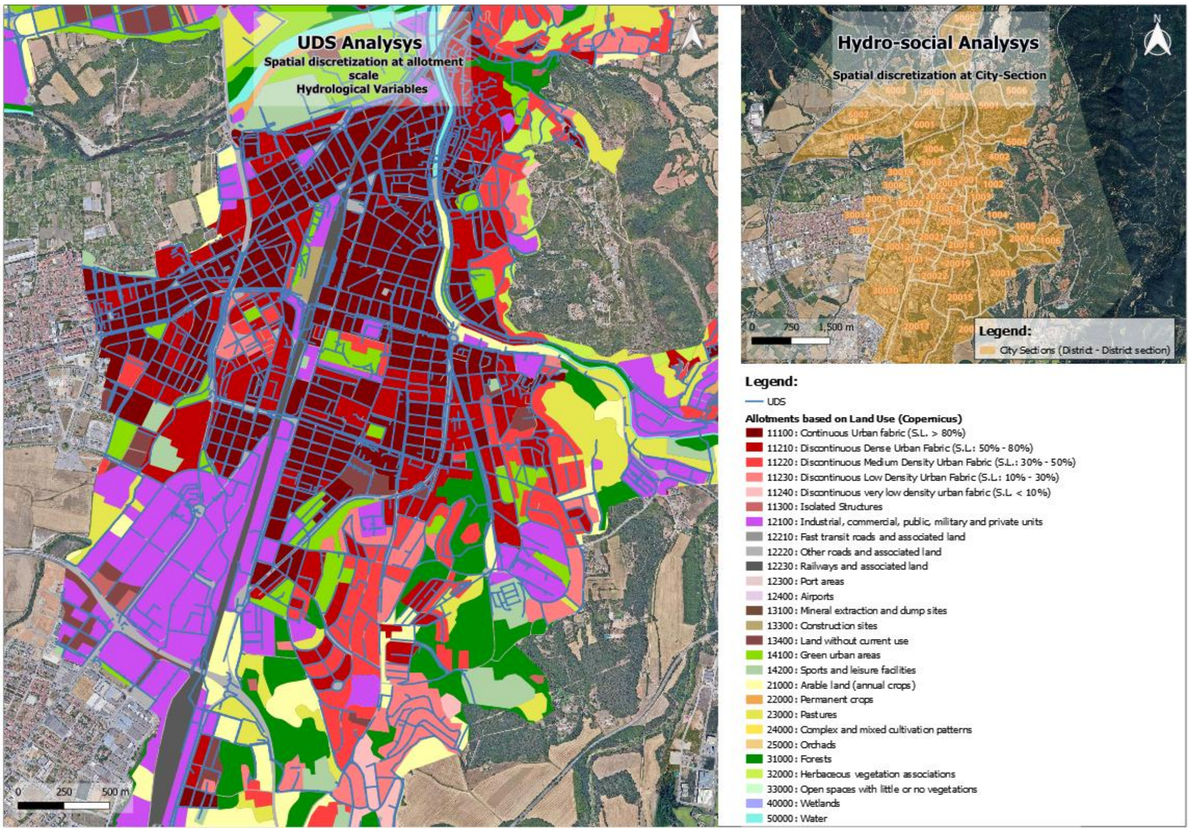

Figure 1. Two spatial scale analysis of hydro-social variables for SUDS location.

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