	Nature4Cities, D2.2 - Expert-modelling toolbox Nature4Cities, D2.3 – NBS database completed with urban performance data https://www.nature4cities.eu/post/applicability-urban-challenges-and-indicators-real-case-studies Nature4Cities, D2.4 - Development of a simplified urban performance assessment (SUA) tool

4.17 Flood peak reduction and delay

Project Name: CONNECTING Nature (Grant Agreement no. 730222)

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Flood peak reduction/delay (Applied and EO/RS combined)	**Water Management**
Description and justification	NBS can help tackle flood risk, for instance by increasing infiltration and evapotranspiration. Changing precipitation patterns due to climate change are expected to exacerbate flooding problems, for instance more intense rainfall events that exceed existing sewage system capacity. Applied approaches to flood peak reduction/delay include monitoring of SuDS performance using in-situ gauges. Typically, a weather station or weather radar data is used in combination with flowrate or water depth monitoring devices (e.g., datalogging v-notch weirs, tipping bucket rain gauges, in-line turbine flowmeters, depth sensors, soil moisture sensors, and infiltrometers). The weather data is used to calculate total rainfall entering the study area (e.g., rainfall depth/unit time x catchment area). Monitoring devices are then used to calculate the rate that water enters and/or leaves a nature-based solution feature. If compared to a control feature (without nature-based solution) or a baseline calculated for the site before the nature-based solution was installed, it is possible to calculate the percentage reduction in absolute height of peak floodwaters and the delay to peak flow. Remote sensing and GIS technologies coupled with computer modelling are useful tools for examining flood events in comparison with flood extent obtained for the annual rainfall using HEC-HMS and HEC-RAS. Using remote sensing data with the help of Flood Hazard Maps for different return periods (10, 20, 50 and 100 years) it is possible to develop, demonstrate and

	validate an information system for flood forecasting, planning and management, which supports assessment of the population vulnerability and physical vulnerability of the lowest administrative division subjected to floods. Key drivers for such monitoring include: • ensuring that systems installed perform as designed following installation; • to assess long-term performance and inform management requirements; • proof of concept for testing new/novel systems; • community engagement with new SuDS installations.
Definition	Assessment of co-benefits/dis-benefits of different SuDS options - in relation to peak flow reduction (e.g., % reduction in absolute height of peak floodwaters) and/or delay (e.g,. increase in time to flood peak in hours)
Strengths and weaknesses	**Applied methods:** Strong evidence in terms of local performance. Can be scaled-up across many sites. Results need to be added into flood management models in order to understand the overall impact across a city/neighbourhood/site. **EO/RS methods:** Most non-structural measures like flood forecasting, proper early warnings and conducting awareness programs among the flood affected community, etc., can be very effective. Modelling of watersheds with modern technology makes this more achievable. Application of GIS and remote sensing technology to map flood areas will make it easy to plan non-structural measures which reduce the flood damages and risks involved.
Measurement procedure and tool	A variety of methods exist from applied/public participation techniques through to earth observation/remote sensing approaches. **Applied/participatory:** Monitoring of SuDS performance using in-situ gauges. Typically, a weather station or weather radar data is used in combination with flowrate or water depth monitoring devices (e.g., datalogging v-notch weirs, tipping bucket rain gauges, in-line turbine flowmeters, depth sensors, soil moisture sensors, and infiltrometers). The weather data is used to calculate total rainfall entering the study area (e.g., rainfall depth/unit time x catchment area). Monitoring devices are then used to calculate the rate that water enters and/or leaves a nature-based solution feature. If compared to a control feature (without nature-based solution) or a

baseline calculated for the site before the nature-based solution was installed, it is possible to calculate the percentage reduction in absolute height of peak floodwaters and the delay to peak flow.

Several projects have reported the methods and results of such monitoring (Asleson et al. 2009; Royal Haskoning 2012; Alves et al. 2014; Perales-Momparler et al. 2014; 2017; Philadelphia Water Department 2014; Connop et al. 2013; 2018; Connop and Clough 2016; Clough and Newport 2017; De-Ville et al. 2018; Susdrain 2018).

A review of selected SuDS that were monitored to test hydrologic/hydraulic efficiency can be found in Lampe *et al.* (2005).

Key drivers for such monitoring include:

- ensuring that systems installed perform as designed following installation;
- to assess long-term performance and inform management requirements;
- proof of concept for testing new/novel systems;
- community engagement with new SuDS installations.

Earth Observation/Remote Sensing:

The use of remote sensing and GIS in water monitoring and management has been long recognized.

Potential application and management is identified in promoting the concept of sustainable water resource management. In conclusion remote sensing and GIS technologies coupled with computer modelling are useful tools in providing a solution for future water resources planning and management to government, especially in formulating policy related to water quality.

Different studies have extracted flood extent from satellite images available for flood events that occurred in a particular period. That can then be compared with the flood extent derived from the flood extent obtained for the annual rainfall using HEC-HMS and HEC-RAS. Based on the flood extent, it is possible to develop, demonstrate and validate an information system for flood forecasting, planning and management using remote sensing data with the help of Flood Hazard Maps for different return periods (10, 20, 50

	and 100 years). This supports assessment of the population vulnerability and physical vulnerability of the lowest administrative division subjected to floods.
Scale of measurement	**Applied methods:** Implementation is typically on a site or street level. It can be scaled-up to much larger scales. However, it is more typical to model the impacts of up-scaling once results have been obtained. **EO/RS methods:** Techniques are applicable at range of geographical scales. Automated methods are particularly valuable for large-scale analyses. High resolution data is needed for finer-scale analysis.
Data source	
Required data	Required data will depend on selected methods, for further details on applied and earth observation/remote sensing metrics refer to Connecting Nature Environmental Indicator Metrics Review Report.
Data input type	Data input types will depend on selected methods, for further details on applied or earth observation/remote sensing metrics refer to Connecting Nature Environmental Indicator Metrics Review Report.
Data collection frequency	Data collection frequency will depend on selected methods, for further details on applied or earth observation/remote sensing metrics refer to Connecting Nature Environmental Indicator Metrics Review Report.
Level of expertise required	**Applied methods:** Expertise needed for design and implementation and management of equipment. Relatively straightforward data analysis once systems are in place. **EO/RS methods:** Expertise in mapping and interrogation of data using GIS software is typically required. Level of expertise required is greater with increasing complexity of software processing.
Synergies with other indicators	**Applied methods:** Data can be fed into large-scale hydraulic modelling to improve accuracy. Can also be combined with broader ecosystem service provision of SuDS (e.g., biodiversity, thermal cooling, air quality, water quality, place-making). **EO/RS methods:** Much of the spatial data required can be used for many other of the mapping indicators, including those for social and economic indicators.
Connection with SDGs	All except SDG5 and SDG7: Reduced impact of flooding; Better irrigation for food production; Reduction of health impacts of flooding; Links to environmental education; Clean water and sanitation possible co-benefit; Job creation; More sustainable infrastructure; Social equality

	in relation to water management; Sustainable urban development; More sustainable water management; Climate change adaptation; Improvements in water management and quality; Habitat enhancement/creation; Environmental Justice; Opportunities for collaborative working
Opportunities for participatory data collection	**Applied methods:** Can include participation in terms of data download, stewardship, etc. **EO/RS methods:** A participatory approach to monitoring flood extent can supplement remote sensing approaches. This can help to strengthen and increase awareness of non-structural measures like flood forecasting and early warning systems.
Additional information	
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4.18 Height of flood peak and time to flood peak measurement

Project Name: UNaLab (Grant Agreement no. 730052)

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Height of flood peak **Time to flood peak**	**Water Management** **Natural and Climate Hazards**
Description and justification	Rapid urbanisation and industrialisation have led to reduced vegetative cover and decreased water storage in the subsurface, as well as the concentration and accumulation of surface runoff in sewage systems due to reduced infiltration into the soil. As a result, the volume of surface runoff as well as the velocity and time to peak storm runoff and baseflow are all increased. Urbanisation also reduces the land coverage of forests and vegetation that help to dissipate the flow energy (Devi, Ganasri & Dwarakish, 2015; Liu, Gebremeskel, De Smedt, Hoffman & Pfister, 2004). The detrimental effects of urbanisation on hydrologic systems are expected to increase in the future due to both increasing urbanisation as well as changes to the global climate, including rising sea levels, glacial retreat, changing precipitation patterns and an increasing frequency of extreme events (Kiehl, 2011).
Definition	Flood peak height is the highest point of the rising limb of a flood hydrograph (describing discharge over time) (m^3/s, cfs, L/s or similar units) Time to flood peak (h)
Strengths and weaknesses	+ Straightforward assessment of degree to which the changes in the local land-use (i.e., change in imperviousness) had an effect on reducing/promoting runoff - Requires *in situ* measurements
Measurement procedure and tool	Assessment of the effectiveness of flood management methods can be performed by different methods. For example, the assessment of runoff can be performed by