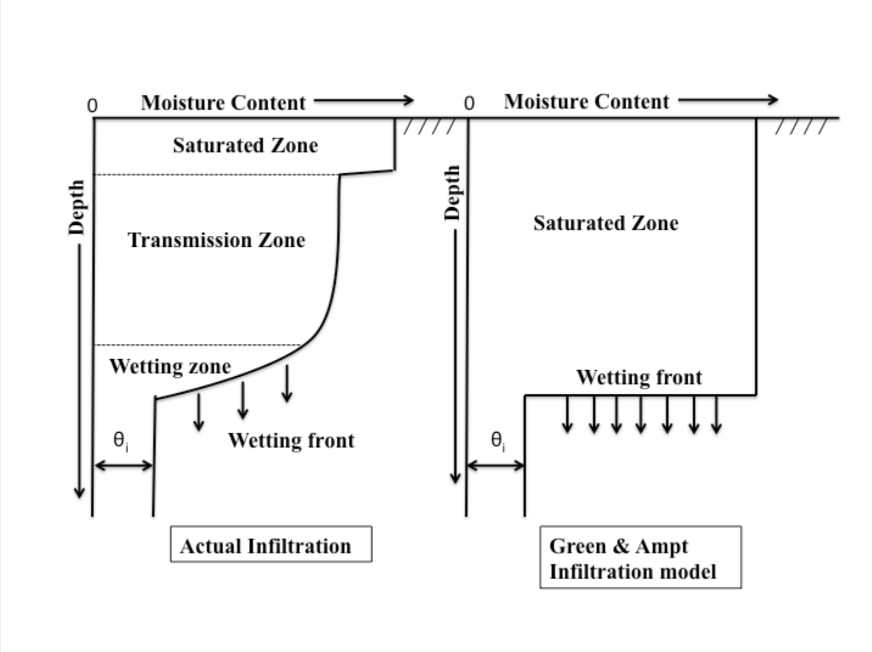

Figure: Soil moisture content distribution in the soil profile modelled by the Green-Ampt model (right) and a typically observed distribution (left) (Neitsch et al., 2011)

4.15 Evapotranspiration rate

Project Name: UNaLab (Grant Agreement no. 730052)

Author/s and affiliations: Laura Wendling[1], Ville Rinta-Hiiro[1], Maria Dubovik[1], Arto Laikari[1], Johannes Jermakka[1], Zarrin Fatima[1], Malin zu-Castell Rüdenhausen[1], Peter Roebeling[2], Ricardo Martins[2], Rita Mendonça[2]

[1] *VTT Technical Research Centre Ltd, P.O. Box 1000 FI-02044 VTT, Finland*

[2] *CESAM – Department of Environment and Planning, University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal*

Rate of evapotranspiration	**Climate Resilience Water Management**
Description and justification	Evapotranspiration (ET) is a combination of two separate processes whereby water is lost from the soil surface by evaporation and from vegetation by transpiration. Water evaporates from surfaces when sufficient heat is supplied for liquid water to transition to water vapour. During transpiration, plant tissues vaporise water, which is then released to the atmosphere through stomatal openings on

	the plant leaf. Nearly all water taken up by plants is released to the atmosphere through transpiration. In addition to the non-uniformity of urban vegetation, shading of urban vegetation by landscape trees and structures and edge effects due to the relatively small scale of urban green space in comparison to commercial crop fields can significantly influence *ET* (Snyder, Pedras, Montazar, Henry, & Ackley, 2015).
Definition	Measured or modelled evapotranspiration (typically expressed in mm per unit time)
Strengths and weaknesses	+ The reference evapotranspiration, ET_o, provides a standard to which: (a) evapotranspiration at different periods of the year or in other regions can be compared; (b) evapotranspiration of other crops can be related (Allen, Pereira, Raes, & Smith, 1998). + Standard, widely-applied technique - Challenging and expensive to measure directly - Requires high level of expertise to apply
Measurement procedure and tool	Evapotranspiration is measured involving specific devices and accurate measurements of various physical parameters or the soil water balance in lysimeters. In practice, ET is commonly calculated using meteorological data. Commercially-available ET monitoring stations are generally meteorological stations that calculate potential ET using monitored temperature, relative humidity, wind speed and direction, solar radiation, and precipitation data. The Penman-Monteith equation is the FAO-recommended standard technique for calculation of reference evapotranspiration, ET_o from crops (Allen, Pereira, Raes, & Smith, 1998). The FAO Penman-Monteith method to estimate ETo is presented in Equation 1: $$ETo = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (1)$$ Where ET_o is reference evapotranspiration [mm day^{-1}], R_n is net radiation at the crop surface [MJ m^{-2} day^{-1}], *G* is soil heat flux density [MJ m^{-2} day^{-1}] ,*T* is mean daily air temperature at 2 m height [°C], u_2 is wind speed at 2 m height [m s^{-1}], *es* is saturation vapour pressure [kPa], *ea* is actual vapour pressure [kPa], *es - ea* is saturation vapour pressure deficit [kPa], *D* is slope vapour pressure curve [kPa °C^{-}1], and *g* is psychrometric constant [kPa °C^{-1}]. Using the Penman-Monteith equation, ET from plant surfaces under standard conditions is determined using an experimentally-determined coefficient (k_c) to relate the ET for

	a specific crop species, ET_c, to ET_o. Thus, for a given crop species: $$ET_c = k_c \times ET_0 \quad (2)$$ For urban landscapes, the landscape coefficient method (LCM), which uses a different set of coefficients rather than k_c to estimate ET, may be more appropriate (Costello, Matheny, Clark, & Jones, 2000): $$ET = k_L \times ET = k_d \times k_s \times k_{mc} \times ET_0 \quad (3)$$ where k_L is a landscape coefficient defined as a product of k_d, a planting density factor, k_S, a species-specific factor, and k_{mc}, a microclimate factor. The modifications of the Penman-Monteith equation for plant-specific conditions can be found in the publications by, e.g., Litvak and Pataki (2016) and Litvak, Manago, Hogue, and Pataki (2016).
Scale of measurement	Plot scale, can be extrapolated using land cover data
Data source	
Required data	Radiation, air temperature, wind speed, vapour pressure, soil heat flux density
Data input type	Quantitative
Data collection frequency	Annually, and before and after NBS implementation
Level of expertise required	High – requires the ability to apply the Penman-Monteith equation and evaluate the results
Synergies with other indicators	Related to *Daily temperature range, Land surface temperature* and *Surface reflectance - Albedo* indicators; a possible consequence of *Green space management* and *Urban regeneration* indicator groups
Connection with SDGs	SDG 11 Sustainable cities and communities
Opportunities for participatory data collection	No opportunities identified
Additional information	
References	Allen, R.G., Pereira, L.S., Raes, D., & Smith, M. (1998). *Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56*. Rome: Food and Agriculture Organization of the United Nations. http://www.fao.org/3/X0490E/x0490e00.htm#Contents

	Costello, L.R., Matheny, N.P., Clark, J.R., & Jones, K.S. (2000). *A guide to estimating irrigation water needs of landscape plantings in California, the landscape coefficient method and WUCOLS III*. Berkeley, CA, USA: University of California Cooperative Extension, California Department of Water Resources. https://ucanr.edu/sites/WUCOLS/ Litvak, E., Manago, K.F., Hogue, T.S., & Pataki, D.E. (2016). Evapotranspiration of urban landscapes in Los Angeles, California at the municipal scale. *Water Resources Research*, 53(5), 4236-4252. Litvak, E. & Pataki, D.E. (2016). Evapotranspiration of urban lawns in a semi-arid environment: An in situ evaluation of microclimatic conditions and watering recommendations. *Journal of Arid Environments*, 134, 87-96. Snyder, R.L., Pedras, C., Montazar, A., Henry, J.M., & Ackley, D. (2015). Advances in ET-based landscape irrigation management. *Agricultural Water Management*, 147, 187-197

4.16 Peak flow variation

Project Name: Nature4Cities (Grant Agreement no. 730468)

Author/s and affiliations: Katia Chancibault[1], Fabrice Rodriguez, Stéphanie Decker[2]

[1] *LUNAM, IFSTTAR, GERS, LEE, route de Bouaye CS4, 44344 Bouguenais, France; katia.chancibault@ifsttar.fr*

[2] *NOBATEK/INEF4, 67 Rue de Mirambeau, 64600 Anglet, France*

Peak Flow Variation	**Water Management**
Description and justification	The peakflow is the maximum value of the flowrate due to a given rain event. It indicates how much the discharge in a river or a stormwater network is impacted by the use of NBS. It can be used to : • assess one NBS type benefit • assess the impact of a combination of NBS set on one large catchment
Definition	Peakflow variation is defined by the relative error in peakflow between the peakflow of the catchment with NBS and the peakflow of a catchment without NBS (% (but flowrates are in l/s or l/s/ha (in case of different catchments comparison))).
Strengths and weaknesses	This indicator will directly assess the impact of NBS in the reduction of the flowrate, which peakflow is a characteristic value.