Ecosystem Service	**Hydrological cycle and flood control**
CICES class name	Hydrological cycle and water flow regulation (Including flood control, and coastal protection)
CICES Section	Regulation & Maintenance (Biotic)
CICES Class code	2.2.1.3

Brief Description

- Regulating the flow of water in our environment
- Living organisms regulate the speed of water flows through ecosystems, improving the storage of water in soils, reducing the frequency or severity of floods and thereby reducing the risk of damage to human property or health

Sample Indicators

Indicator values from			
Experiment or direct measurement		Survey	
Expert assessment		Statistical- or census data	
Model or GIS		Literature values	
Stakeholder participation		Not provided	

Table 1: Field Scale

Indicator	**Unit**	**Indicator values from**
[1] Water (in)filtration capacity	$m^3 * m^{-2} * yr^{-1}$, $mol * m^{-2}$	
[7] Infiltration: unsaturated hydraulic conductivity	$mm * h^{-1}$	,
[5] Water infiltration into the soil (using Beerkan test)	$mm * h^{-1}$	
[7] Deep percolation	mm	,
[4] Drainage below the bottom of the root zone (in the dryland context; low drainage is desirable to avoid salinization)	$mm * yr^{-1}$	

[6] Water drainage	mm * yr^{-1}	,
[10] Modelled drainage	mm * yr^{-1}	,
[15] Water drainage	mm * yr^{-1}	
[14] Water loss through drainage and runoff	mm * yr^{-1}	
[7] Hortonian runoff	mm during growing season	,
[18] Flood regulation: annual number of days with runoff>10mm	#	
[17] Quantity: Share of rain water that evapotranspirates on site (without creating runoff) (urban agriculture)	%	
[2] Water movement and availability: -Soil porosity [%] -Water-filled pore space [%] -Electrical conductivity [µS cm^{-1}] -pH [-]		
[2] Accommodate water entry: -Stable aggregate index [not provided] -Bulk density [g * cm^{-3}] -Earthworms [not provided]		
[5] Soil macroporosity (0 - 10 cm)	Cm	
[3] Soil water holding capacity (0-20 cm), calculated by sample drying & rewetting	g H_2O * g $soil^{-1}$	
[11,12] WHC water holding capacity in topsoil (0-20cm)	%	
[16] Water holding capacity	%	
[13] Available Water Capacity (AWC); the amount of water held between conventional field capacity and wilting point, estimated according to texture and organic matter up to the rooting depth, excluding stones	%	
[6] Mean water content in different soil depths	g H_2O * 100 g dry $soil^{-1}$	,
[14] Soil moisture in topsoil (0-5 cm) and at rooting depth (5-60 cm)	cm * cm^{-3}, %	
[10] Soil water content on a specific date (July, the most water-limited part of the growing season)	g H_2O * g $soil^{-1}$	,

[15] Mean soil humidity in topsoil (0-30cm) during observation period	% dm	
[5] Plant-available soil water (0 - 10 cm)	cm	
[7] Water stress	prop. of days	,
[13] Soil Aridity Index (SAI); average number of days with dry soil in the upper soil layer where roots accumulate	d * yr^{-1}	
[17] Water Quality: Weighted average concentration of TOC, TIC, NO^{-3}, and NH^{+4} in leachate (Retention of elements and molecules, leaching, biodegradation)	mg * l^{-1}	
[8] Soil hydrological functions indicator based on a principal component analysis (PCA) of 12 variables assessed at 0-10 cm and 10-20 cm. Variables included: -Volumetric and gravimetric moisture content -Micro (<0.03 µm), meso (0.03–3 µm) and macro (>3 µm) porosity -Plant available water retained between water holding capacity and wilting point -Aggregate stability, bulk density, resistance to vertical penetration, shear strength resistance, Variables with significant contribution (>50 % of the maximum value) to either of the first two principal component axes were selected. Their contribution to PCA axes 1 and 2 multiplied by the overall variability explained by each PCA axis. These weighted factors were summed up and scaled to a range of 0.1 - 1.0.	-	
[9] Indicator value calculated as: $$I = \frac{\sum \quad \mid log\,(\frac{i}{i_{max}})\mid}{n}$$ With: I – indicator value, i – variable i measured, i_{max} – maximum ecologic potential of variable i in benchmark reference, n – number of variables. Where performance is considered better than in the benchmark and deviation, therefore, has a positive effect, $\mid log\,(\frac{i}{i_{max}})\mid$ is subtracted from the sum instead of added. For this ES, variables were: -Soil organic matter [% dw] -Earthworm abundance [# * m^{-2}] -Bacterial biomass [mg C * g dw^{-1}] -Number of earthworm taxa [-]	-	,

Table 2: Farm Scale

Indicator	Unit	Indicator values from

[20] Rate of water infiltration into the soil	mm * ha^{-1}	
[19] Four-level index based on the number of days streamflow is extended through seepage losses in channel irrigation systems (which recharge groundwater aquifers).	Index poor-fair-good-excellent	
[19] Flood protection: Four-level index based on share of water lost through seepage in open channel irrigation [%]. The higher the value, the better.	Index poor-fair-good-excellent	

Table 3: Regional Scale

Indicator	Unit	Indicator values from
[21] Water holding capacity	m^3 * ha^{-1}	,
[22] Water retention capacity	m^3 * ha^{-1}	
[30] Soil water storage capacity. Values were normalized [0-1] using benchmark values where available and observed values otherwise.	mm	
[22] Runoff coefficient	-	
[23] Mitigated runoff: difference between total input precipitation by storm event and runoff	mm, m^3 * km^{-2}	
[23] Mitigated runoff: percentage of mitigated flood water (intercepted, absorbed, or detained flood water, divided by total precipitation) multiplied by the number of beneficiaries at risk of flooding	-	
[23] Mitigated runoff: runoff Curve Number (CN). The CN determines the approximate amount of direct runoff from a rainfall event in a particular area.	Range 30 - 100	
[18] Inverse indicator. Flood regulation: annual number of days with runoff>10mm	#	
[24] Flood regulation: (runoff) curve number	-	
[36] Number of extreme (runoff) events	# * yr^{-1}	
[22] Groundwater recharge	m^3 * ha^{-1}	
[35] Baseflow regulation, calculated using InVEST model	Not provided	
[22] Evapotranspiration	mm	

[22] Share of sealed soils	%	
[30] Soil water infiltration capacity. Values were normalized [0-1] using benchmark values where available and observed values otherwise.	cm * h^{-1}	
[37] Water infiltration: annual subsurface water flow	mm * y^{-1}	
[31] Water yield: rainfall - actual annual evapotranspiration (using InVEST's Hydropower Water Yield model)	m^3 * yr^{-1} * grid $cell^{-1}$	
[25] Moderation of extreme events: Percentage of the total area of the region that contains native vegetation	%	
[27] Water regulation index. The index is based on soil physical characteristics, including volumetric and gravimetric moisture content, porosity, plant available water (based on water retention curves), aggregate stability, bulk density, penetration resistance and shear strength resistance.	Index 0.1 - 1	
[32] Water flow management: expert-based index for ES provision by land cover class [1-5], multiplied by the area of the land cover class	km^2	, ,
[32] Water flow management value: expert-based index for ES provision by land cover class [1-5], multiplied by the area of the land cover class and a literature-based monetary value of the ecosystem service	km^2, $ * ha^{-1} * yr^{-1}	, ,
[27] Bio-indicator: Presence of specific ant species is used as an indicator for high, medium or low provision of this ecosystem service. Suitable indicator species must first be identified by correlation between presence of species and ecosystem service provision.	-	
[26] Flood regulation score: preventative and mitigation functions of vegetation and soils. Score calculated after Nedkov and Burkhard (2012), using the parameters: interception, infiltration, surface runoff and peak flow.	Score 0 - 100	,
[28] Flood protection: Values are assigned based on land cover classes. The matrix defined by Burkhard et al., 2012 (DOI:10.1016/j.ecolind.2011.06.019) was adapted and used in this study.	Index 0 - 5	
[29] Reduction of flash flood risk: total area of flooded buildings (relative to total catchment area) in a 100-year rainfall event.	%	,
[32] Flood control: expert-based index for ES provision by land cover class [1-5] multiplied by the area of the land cover class	km^2	, ,
[32] Flood control value: expert-based index for ES provision by land cover class [1-5], multiplied by the area of the land cover class and a literature-based monetary value of the ecosystem service	km^2, $ * ha^{-1} * yr^{-1}	, ,

[33] Flood regulation: Expert-/stakeholder rating of how much of this ES can be provided by a landscape (represented by a land use map), using a 6-point Lickert-scale	Scale none - highest capacity	
[33] Flood regulation: Expert-/stakeholder rating based on pairwise comparisons of landscapes (represented by land use maps) in an Analytical Hierarchical Process (AHP). Experts select the landscape with higher capacity for providing this ES and rate the difference between the two landscapes	Rating 1: equal capacity - 9: absolute preference of one landscape	
[34] Flood regulation, calculated as: maximum number of annual flood events in time series - average number of annual flood events during time series. Only events where damages exceed a certain cost are counted.	#	
[38] Flood regulation supply Indicator: normalized total river discharge within five days after a modelled precipitation event. Calculated with the hydrological model STREAM	Index 0 - 1	
[40] Flood risk: expected cost of temporary disruption of transport infrastructure	$\$ * ha^{-1} * yr^{-1}$	,
[40] Flood risk: expected cost damages to residential properties	$\$ * ha^{-1} * yr^{-1}$	,
[39] Disturbance control, calculated as: $$DC = I_W * O_W * 1.25$$ With: DC – Disturbance control, I_w – water input to the system, calculated as rainfall * (1−runoff coefficient) and scaled to a range of [0 – 1000], O_w – water bodies occupancy percentage and flat floodplain area [0 – 1]	-	
[41] Flood regulation supply: continuous index, based on the variability of the peak discharge at the outlet of a catchment in dependence of land use and soil distribution	-	
[40] Floodplain capacity to store water: time to fill storage capacity (T) [days], calculated as: $$T = \frac{S}{86400 * Q_{med}}$$ With: T – Index of flood storage [d], S – Storage volume [m^3], Q_{med} – Median annual flood [$m^3 * s^{-1}$]	d	,
[40] Space for water (in floodplains): theoretical proportion of floodplain area flooded annually, calculated by dividing the area of the indicative floodplain by the total area of the floodplain, and multiplying by the annual flood probability.	-	,

[42] Flood regulation supply index. The index represents the capacity of catchments to retain precipitation as a function of a catchments' topography and hydrology, water holding capacity of the soil, and land use.	0 - 1	
[45] Volume of irrigation water	n/a	
[45] Volume of surface water used for irrigation	n/a	
[45] Volume of groundwater used for irrigation and in restoration consortiums	n/a	

Table 4: National Scale

Indicator	Unit	Indicator values from
[43] Water quantity: Expert assessment for each land use class, based on the indicator: above-ground runoff [not provided]	very negative (−3) to very positive (+3)	

Table 5: Multinational Scale

Indicator	Unit	Indicator values from
[43] Flood regulation supply: continuous index, based on the variability of the peak discharge at the outlet of a catchment in dependence of land use and soil distribution	0 - 1	
[44] Flood protection: Values are assigned to Corine land cover classes, based on values published by Burkhard et al. (2009; DOI: 10.3097/LO.200915) and modified for the context of riparian zones.	Index 0 - 5	

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