Ecosystem Service	**Chemical condition of freshwaters**
CICES class name	Regulation of the chemical condition of freshwaters by living processes
CICES Section	Regulation & Maintenance (Biotic)
CICES Class code	2.2.5.1

Brief Description

- Controlling the chemical quality of freshwater
- Maintenance of good chemical condition of freshwater by plant or animal species that enable human use
- This class should be used "where anthropogenic waste and pollution input is minimal, and a more natural regime maintains the quality of water bodies concerned and where this contributes to human well-being" (Haines-Young, 2023). For mitigating effects of strong anthropogenic contaminations, classes 2.1.1.1 (Biotic remediation of waste) and 2.1.1.2 (Biotic filtration, sequestration and storage of waste) should be used.

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**
[5] Seepage rate - amount of water that leaves the rooting zone toward the groundwater table	mm * yr^{-1}	
[6] Seepage rate - amount of water that leaves the rooting zone toward the groundwater table	mm * yr^{-1}	
[2] Concentration of nitrates in drained water	mg NO_3^- * l^{-1}	

[5] Nitrate concentration in seepage water	mg * l^{-1}	
[6] Nitrate concentration in seepage water	mg * l^{-1} * yr^{-1}	
[10] Soil mineral nitrogen content at the end of summer (0-90 cm, measured between October 1st and November 15th)	kg * ha^{-1}	,
[4] Nitrate leaching	kg NO_3^{-}N * ha^{-1} * yr^{-1}	
[9] Nitrate leaching prevention: nitrate concentration in drained water	mg NO_3^{-} * l^{-1}	
[8] NO_3^{-} loss through leaching and runoff, following cover crop or fallow period	kg * ha^{-1}	
[11] Groundwater: annual total nitrate (NO_3-N) leached at the bottom of the soil profile	kg * ha^{-1}	
[1] Nitrogen mineralization	kg N_{tot} * ha^{-1} * yr^{-1}	
[11] Surface water: annual total phosphorus yield in runoff	kg * ha^{-1}	
[8] Dissolved P loss through leaching and runoff, following cover crop or fallow period	kg * ha^{-1}	
[7] Total P leached from experimental pot 1 day after applying phosphorus solution	µg	
[5] Phosphorus loss (particulate phosphorus removed by water erosion)	kg * ha^{-1} * yr^{-1}	
[6] Phosphorus loss (particulate phosphorus removed by water erosion)	kg * ha^{-1} * yr^{-1}	
[6] Erosion by water	t * ha^{-1}	
[2] Concentration of pesticides in drained water	µg * l^{-1}	,
[6] Share of years within management period in which protection plant products were used	%	
[42] Mineral nitrogen content in soils (0–90 cm), calculated as the sum ofNO_3^{+}-N and NH_4^{-}-N	kg/ha	
[42] Soil phosphorus extractable in calcium-chloride (0–10 cm)	p.p.m.	
[42] Soil phosphorus (0–10 cm) measured as Olsen-P	p.p.m.	

[3] Natural attenuation/ clean groundwater: Indicator value calculated as: $$I = \frac{\sum \quad \lvert log\,(\frac{i}{i_{max}})\rvert}{n}$$ 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, $\lvert log\,(\frac{i}{i_{max}})\rvert$ is subtracted from the sum instead of added. For this ecosystem service, variables were: -Soil organic matter [% dw] -Bacterial biomass [mg C * g dw^{-1}] -pH in KCl -Physiological diversity bacteria [bBiolog. CLPP: Hill's slope] -Water-soluble P (Pw) and extractable P (PAL)		 , 

Table 2: Farm Scale

Indicator	**Unit**	**Indicator values from**
[14] Share of nitrogen retained during water passage between agricultural sub-catchment and sea	%	
[12] Share of waterways protected by buffers. The index is calculated by dividing the observed value with a target value. Target values may be average or maximum values found in region, or empirical values from literature. If the calculated index is higher than 1, it is set to one.	Index 0 - 1	
[13] Macroinvertebrates: index based on number of aquatic macroinvertebrates species	poor - fair - good - excellent	
[13] Turbidity: index based on the turbidity of water in the stream channel	poor - fair - good - excellent	
[14] Share of farmers that express clearly a value and care for the health of the land	%	

Table 3: Regional Scale

Indicator	**Unit**	**Indicator values from**
[20] Freshwater supply: Annual groundwater recharge	cm * yr^{-1}	 , 
[15] N export with seepage water	kg N * ha^{-1}	

[28] Nitrogen leaching	kg N * ha^{-1} * yr^{-1}	
[31] Nitrate leaching	kg * ha^{-1} * yr^{-1}	
[11] Groundwater: annual total nitrate (NO_3-N) leached at the bottom of the soil profile	kg * ha^{-1}	
[33] Potential nitrate leaching, estimated from agricultural productivity and associated inputs	kg NO_3^- * ha^{-1} * yr^{-1}	
[23] Risk of nitrate leaching: exchange frequency of the soil water in the root layer. Infiltration rate divided by field capacity	%	
[14] Share of nitrogen retained during water passage between agricultural sub-catchment and sea	%	
[35] Water purification: Nitrogen retention	g N * yr^{-1} * m^{-2}	
[21] Groundwater quality: Probability of groundwater nitrate concentration <3.0 mg per litre	0 - 1	, ,
[26] Nitrogen retention at watershed level calculated with InVEST's Nutrient Retention Model. Calculation based on nitrogen loading and vegetation filtering value for different land-use classes.	t N * yr^{-1} * grid $cell^{-1}$	
[29] Total nitrogen export that reaches the nearest stream, calculated with InVEST model	t * ha^{-1}	
[11] Surface water: annual total phosphorus yield in runoff	kg * ha^{-1}	
[20, 21] Surface-water quality: Annual phosphorus loading, calculated using the InVest model	kg * ha^{-1}	, ,
[29] Total phosphorus export that reaches the nearest stream, calculated with InVEST model	t * ha^{-1}	
[15] P export with seepage water	kg N * ha^{-1}	
[28] Phosphorus loss	kg P * ha^{-1} * yr^{-1}	
[18] Phosphorus retention, calculated with InVEST model	kg * ha^{-1}	
[16] Total N and P loading in lakes	t * yr^{-1}	
[16] Outflow N and P loading in lakes	t * yr^{-1}	

[16] N and P retention in lakes	$t * yr^{-1}$	
[16] N and P concentration in lakes	$mg * l^{-1}$	
[25] Water quality: concentrations of nitrogen, phosphorus, and sediments (including suspended solids and turbidity)	$mg * l^{-1}$	
[30] Leakage of nutrients	$kg * ha^{-1} * yr^{-1}$	
[30] Turnover rates of nutrients, e.g., N, P	$kg * yr^{-1}$	
[30] Total dissolved solids	$mg * l^{-1}$	
[30] Decomposition rate of organic matter	$kg * ha^{-1}$	
[34] Water quality of freshwater ecosystems	Not provided	
[30] Area occupied by riparian forests	ha	
[24] Share of natural forest cover in municipality's surface. Values were normalized [0-1] using benchmark values where available and observed values otherwise.	%	
[17] Area of buffer strips alongside rivers. Buffer strips are defined as areas connected to the river system and belonging to the land use classes: pasture, open space/heathland, woodland/single tree, tree hedgerow/hedgerow, arable field boundaries, grassland boundaries, deciduous tree dominated forest, coniferous tree dominated forest, or peatland	m^2	
[17] Arable land uphill from buffer strips alongside rivers	m^2	
[17] Arable land on slopes steeper than 3% uphill from buffer strips alongside rivers	m^2	
[17] Potential erosion from buffer strips and the area uphill from them (using RUSLE equation)	$t * yr^{-1}$	
[19] Mechanical filtration capacity: infiltration capacity, calculated as: $$IC = s_p * (1 - s)$$ With: IC – infiltration capacity, s_p – soil permeability [cm/day], s – share of anthropogenic surface sealing)	$cm * d^{-1}$	,

[19] Physicochemical filtration capacity, calculated as: $$C = CEC_{eff} * (1 - s)$$ With: C – physicochemical filtration capacity, CEC_{eff} – effective cation exchange capacity, s – share of anthropogenic surface sealing	cmol(+) * kg dm^{-1}	,
[22] Water purification: values for 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	
[27] Mediation of water pollution such as excess nitrogen removal: expert based index for ecosystem service supply by land cover class [1-5], multiplied by the area of the land cover class	km^2	, ,
[27] Mediation of water pollution such as excess nitrogen removal value: expert based index for ecosystem service supply 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	\$ * ha^{-1} * yr^{-1}	, ,
[32] Water purification and provision, calculated as: $$W = NPP * (1 - VCNPP) * IC_s * S_{cf} * 1.75$$ With: W – water purification and provision, NPP – Net Primary Production calculated from NDVI-values and expressed on a relative scale set to [0 – 1000], VCNPP – coefficient of variation of NPP [0 – 1], IC_s – soil infiltration capacity [0 – 1], S_{cf} – slope average correction factor of the study area [0 – 1]	-	
[32] Waste purification, calculated as: $$W = NPP * (1 - VCNPP) * I_w * O_w * 1.75$$ With: W – waste purification, NPP – Net Primary Production [0 - 1000], VCNPP – coefficient of variation of NPP [0 – 1], I_w – water input to the system [0 – 1], O_w – water bodies occupancy percentage and flat floodplain area [0 – 1]	-	
[14] Share of farmers that express clearly a value and care for the health of the land. Values were scaled to [0-1]	%	
[40] Volume of purified water	m^3/(km^2 *year)	
[40] Mass of a specific nutrient retained	ton/ (km^2 * year)	
[41] Area of undisturbed creek banks that serve as buffers to pesticide and fertilizer runoff	n/a	

Table 4: National Scale

Indicator	Unit	Indicator values from
[37] Denitrification capacity	kg N * ha^{-1} * yr^{-1}	

[37] Phosphorus sorption capacity	kg P * ha^{-1} * yr^{-1}	
[38] Chemical status	Not provided	
[38] Ecological status	Not provided	
[34] Water quality of freshwater ecosystems	-	
[36] Water quality: Expert assessment for each land use class, based on the indicators: nutrient efficiency; pesticides (units not given)	very negative (−3) to very positive (+3)	
[38] Groundwater: Indicators of groundwater quality	Not specified	
[38] Wetlands: Potential of water purification of wetlands	Not specified	

Table 5: Multinational Scale

Indicator	Unit	Indicator values from
[34] Water quality of freshwater ecosystems	-	
[35] Water purification: Nitrogen retention	g N * yr^{-1} * m^{-2}	
[39] Water purification: values for 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	

Table 6: Global Scale

Indicator	Unit	Indicator values from
[34] Water quality of freshwater ecosystems	-	

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