

**Fourth International Conference on Remote Sensing and
Geoinformation of the Environment 2016
4-8 April, 2016, Paphos, Cyprus**

A new spatial basis for river monitoring and management under the E.U. Water Framework Directive in Cyprus



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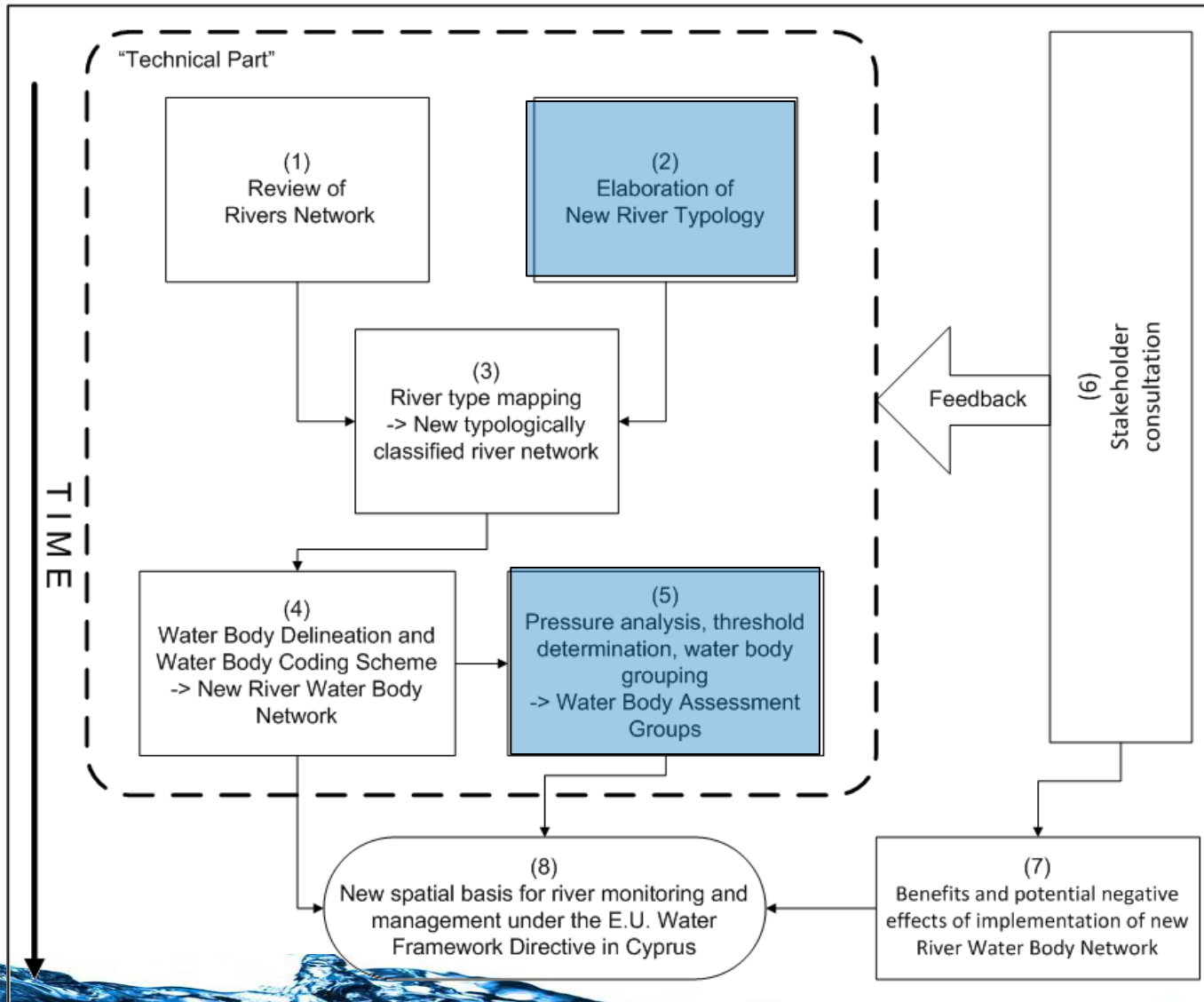


Why a new spatial basis?

- **Significant shortcomings in the 1st River Basin Management Plan (2009) of the Water Framework Directive (2000/60/EC; WFD):**
 - River network determination: Lack of consistent criteria
 - River typology: Lack of quantitative knowledge of hydrological regimes of Cyprus rivers – especially on the different types of temporary rivers
 - River water body delineation: Pressures were not taken into account -> water bodies with inhomogeneous pressure situation
 - River water body assessment groups existed but proved inapplicable
- **Aim for 2nd River Basin Management Plan (2015):**
 - Rectify the “technical deficiencies” of the 1st RBMP



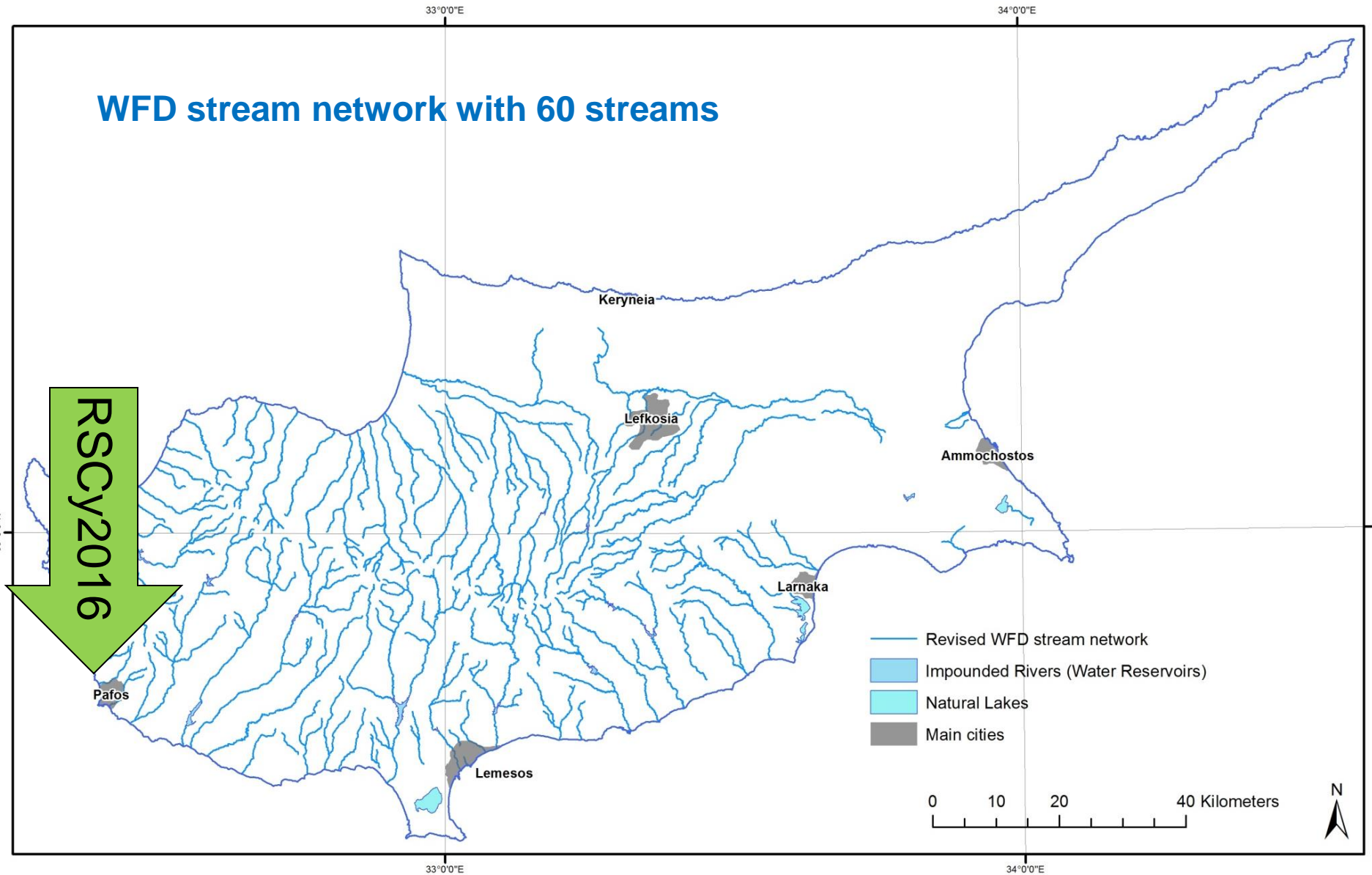
Methodology – project components



Review of the WFD river network

Revised WFD stream network

WFD stream network with 60 streams



Elaboration of the new river typology (1)

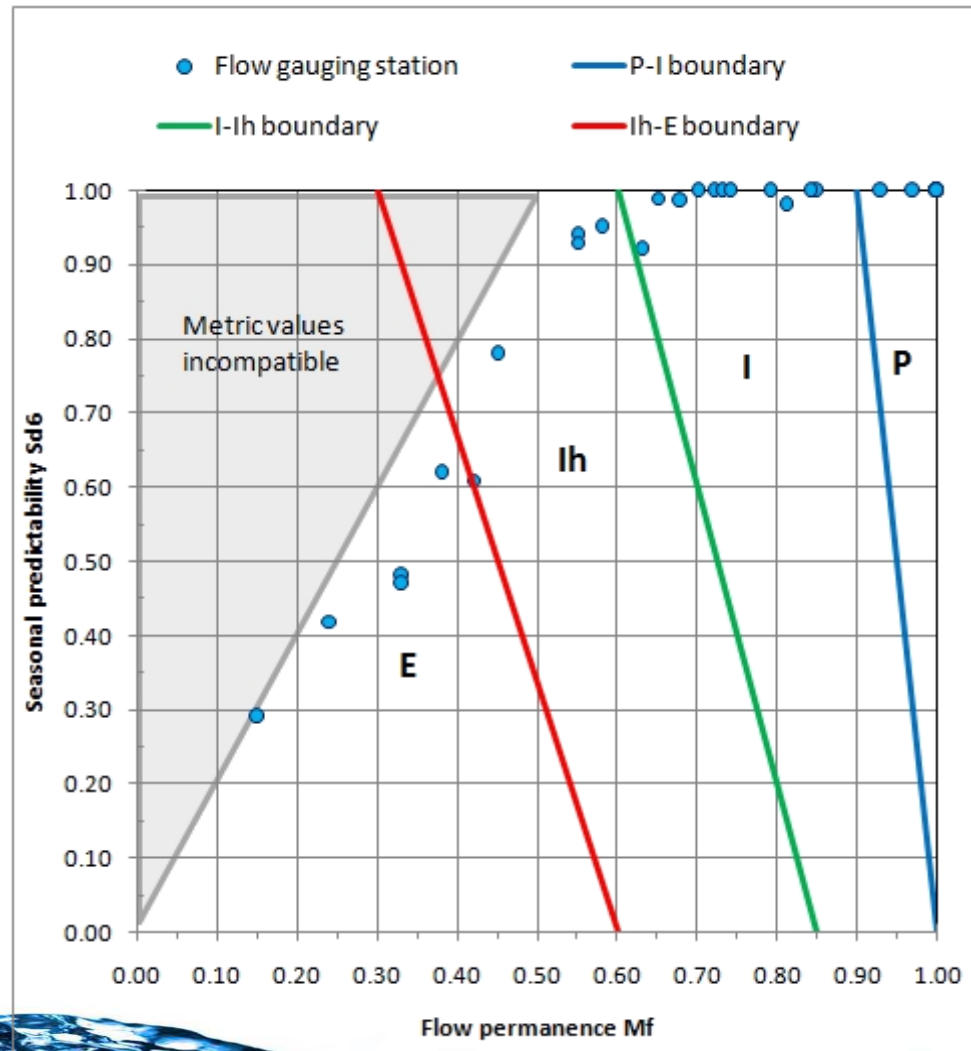
- The flow regime is of immense importance for Mediterranean lotic ecosystems -> the new Cyprus river typology is based on the different flow regimes present on the island
- Base data: recorded stream flow data from 29 Cyprus gauges
- Adopted method: Temporary Stream Regime Tool (TSR-Tool, Gallart et al. 2012)
 - Two metrics (Mf, Sd6) plotted as x,y data on the “TSR-plot”
 - Four stream types (flow regimes): Perennial (P), Intermittent (I), Harsh-Intermittent (Ih) and Ephemeral-Episodic (E)
 - Stream types directly relate to the relevance of biological communities for WFD monitoring purposes



Elaboration of the new river typology (2)

TSR-plot with Cyprus data

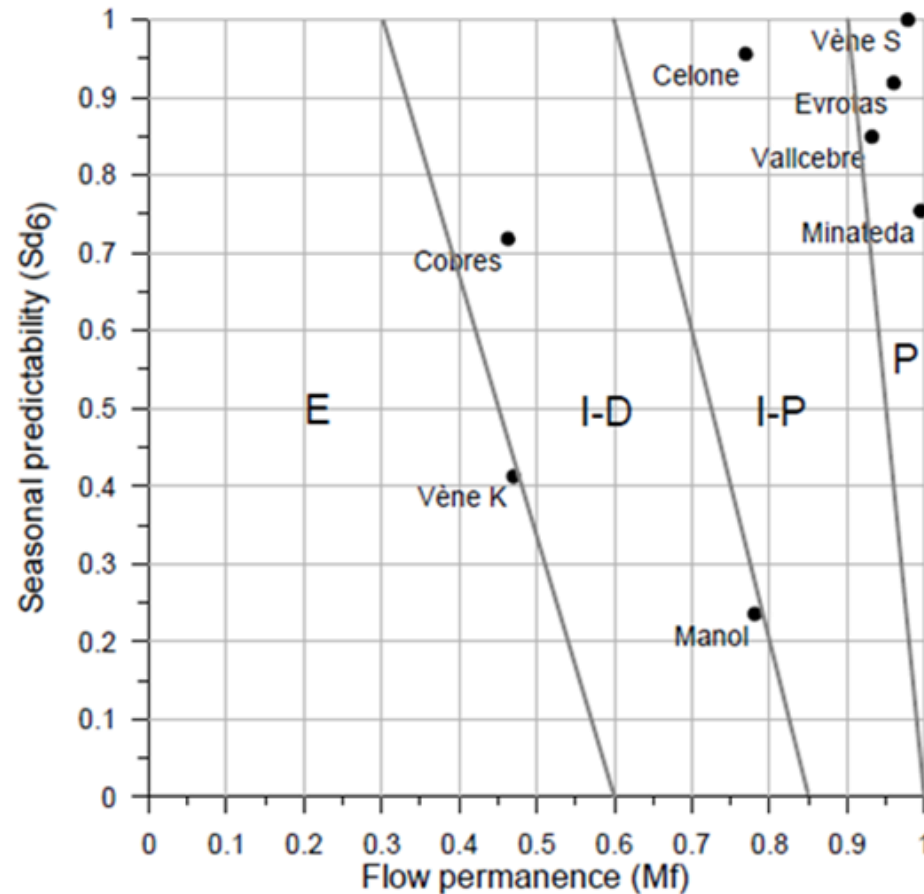
- Data covers the whole range of flow regimes
- Distinctive alignment of the plotting positions along a gradient



Elaboration of the new river typology (3)

Comparison with other TSR-tool applications

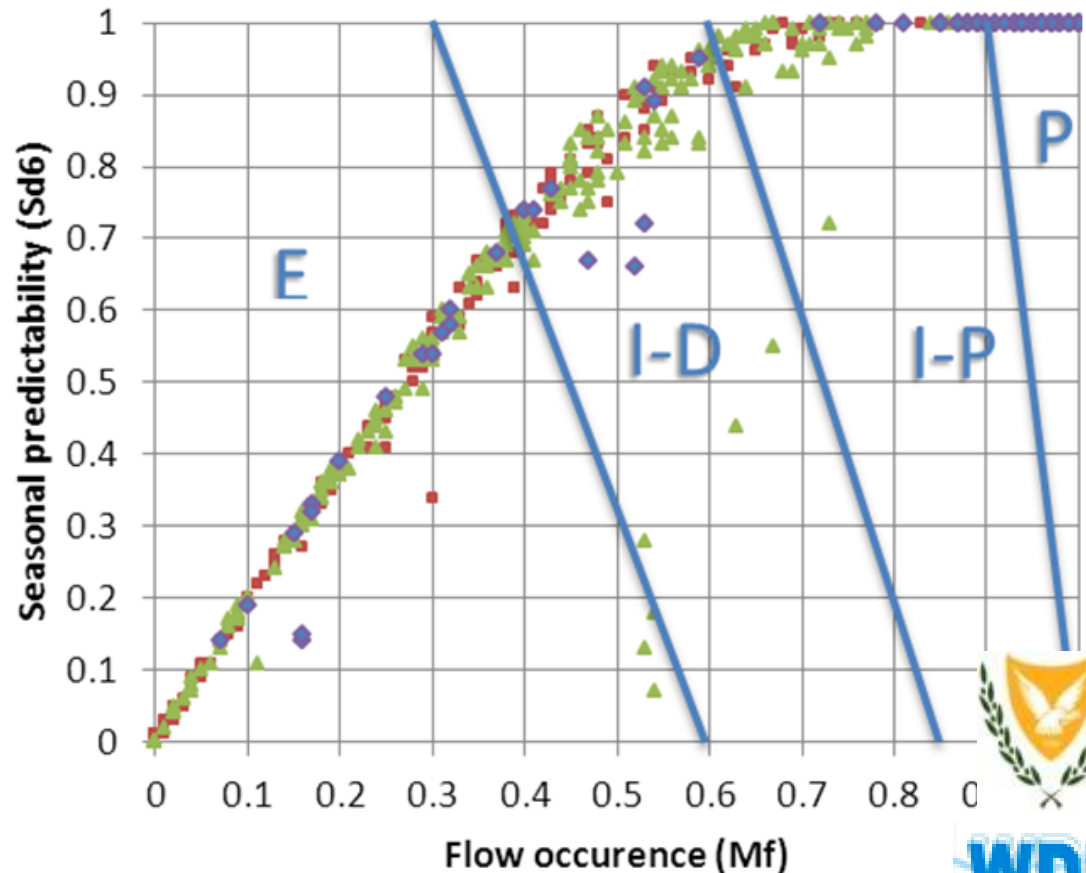
- TSR-Plot from Gallart et al. 2012 – Original proposal of the TSR-Tool (FP7 project “Mirage”)
- Data from several Mediterranean countries
- No alignment of the plotting positions



Elaboration of the new river typology (4)

Comparison with other TSR-tool applications

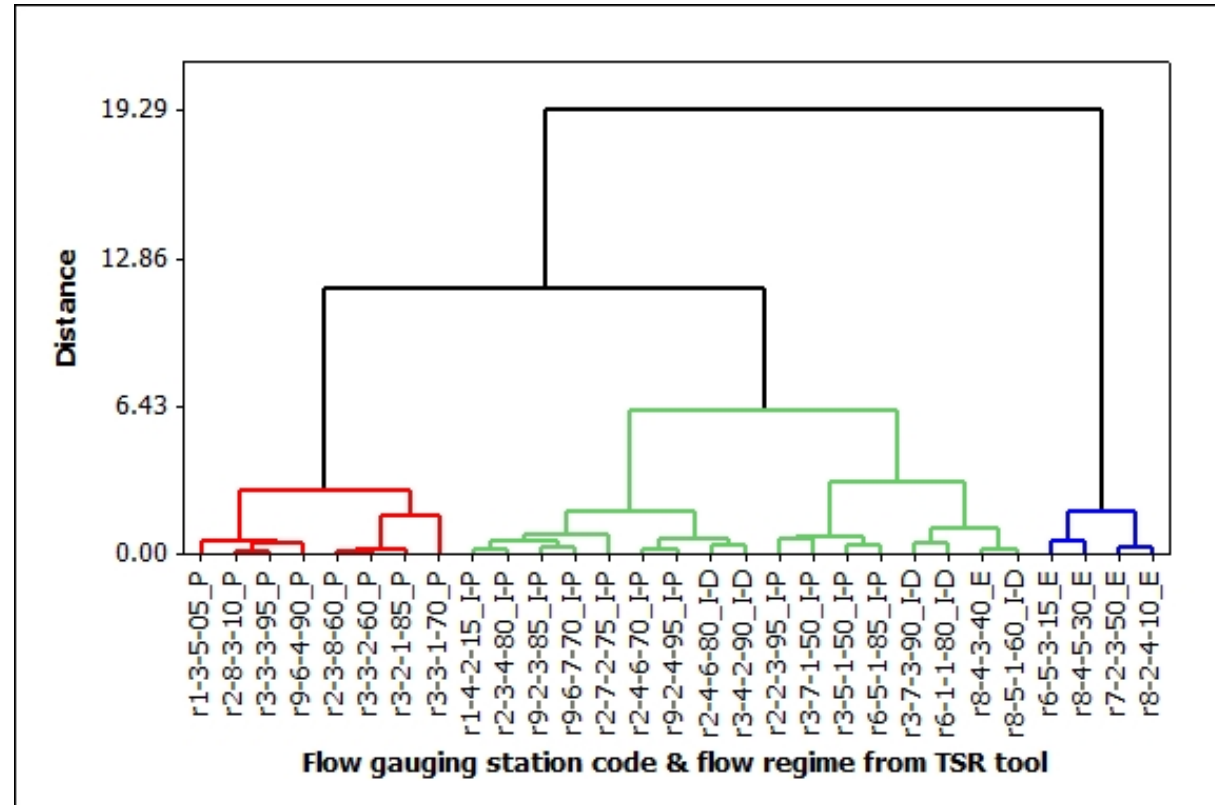
- TSR-Plot from Cazemier et al. (2011) from Evrotas river in Greece (modelled data)
- Similar alignment of the plotting positions as with Cyprus data
- A generally valid Mediterranean relationship?



Elaboration of the new river typology (5)

Cross-checking of TSR-tool results

- Cluster analysis
- Input: hydrological parameters as in similar studies in the Mediterranean area
- Results confirm outcome from TSR-tool
- Clear partition into stream types Perennial, Intermittent and Ephemeral-Episodic streams



Input parameters:

- number of zero flow days
- base flow contribution (fixed interval method)
- $\ln(\text{flashiness index})$



Elaboration of the new river typology (6)

New Cyprus River Types' catchment characteristics

Type code	River flow category (Temporary Stream Regime - TSR ²)	Type name	Altitude ⁺ [m]	Geology ⁺ - Coverage of catchment with Troodos mantle and plutonic rocks [%]	Geology ⁺ - Coverage of catchment with Troodos rocks [%]	Geology ⁺ - Coverage of catchment with Sedimentary and Quaternary rocks [%]	Annual precipitation 1971-2000 [mm]	Mean water slope [%]	Mean catchment slope [%]
P	Perennial (P)	Perennial mountain streams	1051 (+/- 235)	60 (+/-43)	95 (+/-12)	5 (+/-12)	753.4 (+/-82)	10.8 (+/-4.3)	23.9 (+/-4.3)
I	Intermittent-Pool (I-P)	Intermittent streams	660 (+/- 211)	16 (+/-21)	86 (+/-31)	14 (+/-31)	569.6 (+/-65.9)	6.9 (+/-2.5)	20.9 (+/-5.5)
Ih	Intermittent-Dry (I-D)	Harsh intermittent streams	580 (+/- 208)	11 (+/-20)	98 (+/-4)	2 (+/-4)	479.2 (+/-48.2)	7.5 (+/-3.5)	18.8 (+/-4.6)
E	Ephemeral-Episodic (E)	Ephemeral and/or episodic streams	249 (+/- 146)	1 (+/-1)	45 (+/-41)	55 (+/-41)	378.2 (+/-37.5)	2.2 (+/-1.1)	7.3 (+/-3.5)

⁺) obligatory factors of Annex II of the WFD



Elaboration of the new river typology (7)

New Cyprus River Types'

hydrological & flow regime characteristics

Type code	River flow category (TSR regime ³)	Type name	Mean annual flow [m ³ /s]	Specific catchment yield [L/s/km ²]	Baseflow contribution (Fixed interval method) ⁴ [%]	R-B index (Flashiness index) ⁵	Number of zero days ⁶	Mean annual coeff. of variation of mean daily streamflow ⁷	Mean coeff. of variation of mean annual runoff (CVMAR)
P	Perennial (P)	Perennial mountain streams	0.257 (+/- 0.115)	7.0 (+/-3.9)	84 (+/-6)	0.19 (+/-0.07)	4.5 (+/-11.9)	1.9 (+/-0.7)	0.62 (+/-0.08)
I	Intermittent-Pool (I-P)	Intermittent streams	0.177 (+/- 0.146)	3.0 (+/-1.6)	72 (+/-7)	0.34 (+/-0.12)	120 (+/-31)	3.6 (+/-0.9)	0.75 (+/-0.11)
Ih	Intermittent-Dry (I-D)	Harsh intermittent streams	0.090 (+/- 0.130)	2.5 (+/-1.3)	65 (+/-14)	0.42 (+/-0.20)	207 (+/-22)	4.4 (+/-0.9)	0.99 (+/-0.28)
E	Ephemeral-Episodic (E)	Ephemeral and/or episodic streams	0.060 (+/- 0.053)	0.7 (+/-0.5)	23 (+/-19)	1.15 (+/-0.40)	325 (+/-40)	10.7 (+/-7.9)	1.58 (+/-0.43)

³ (Gallart et al., 2012, Prat et al., 2014)

⁴ (Sloto and Crouse, 1996)

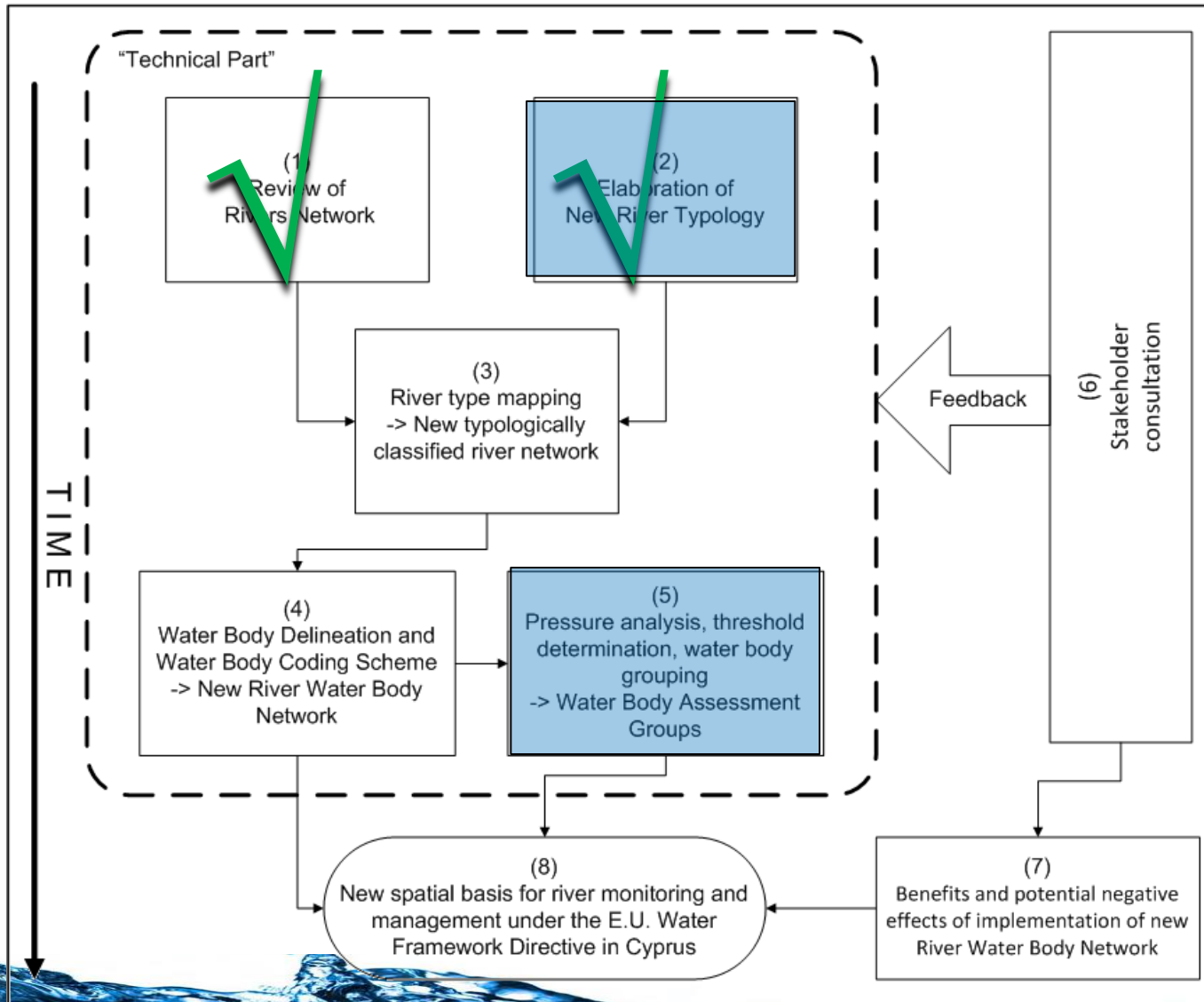
⁵ Baker et al. (2004), Richards-Baker flashiness index

⁶ Calculated using the IHA software (The Nature Conservancy, 2009)

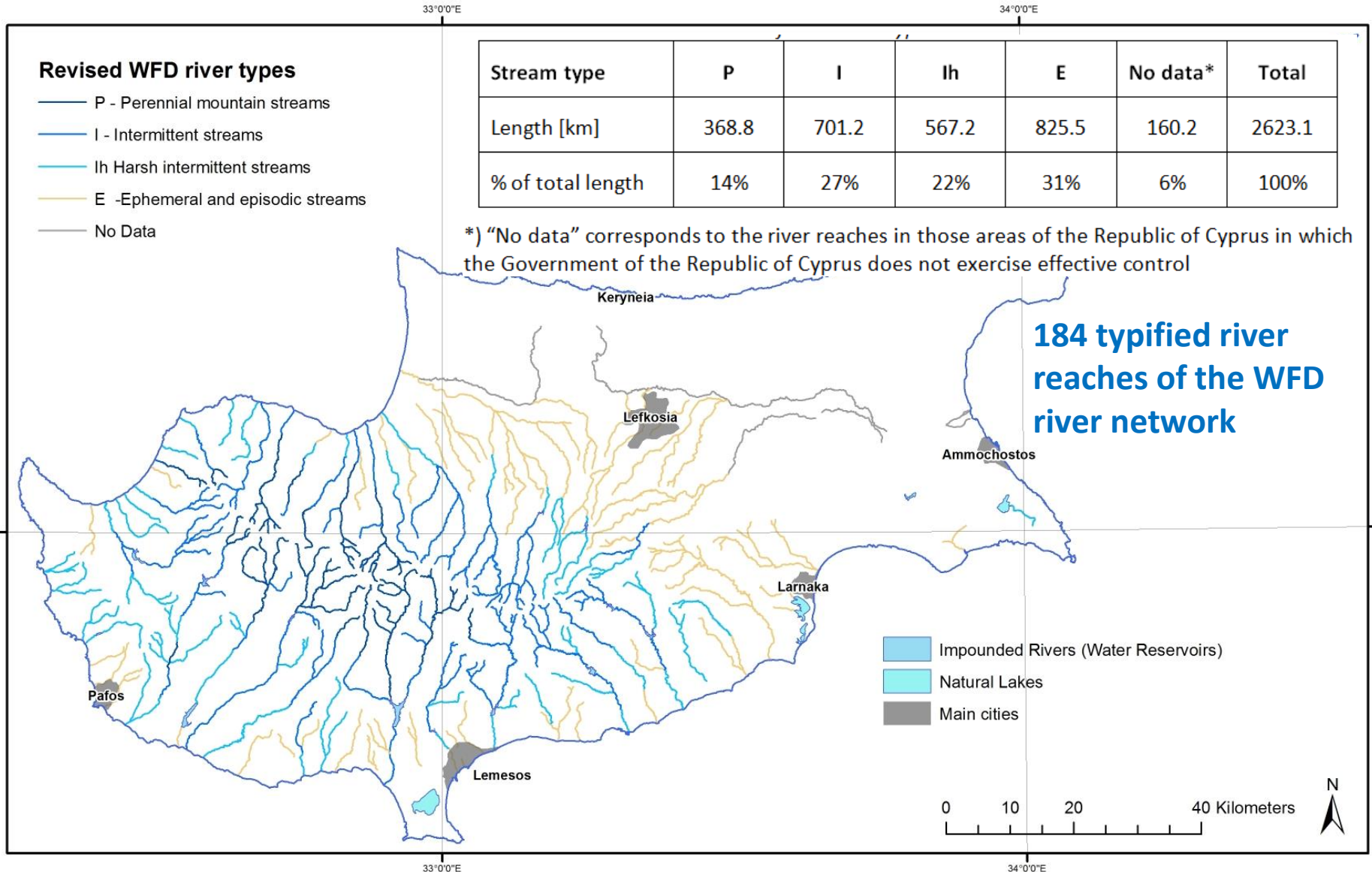
⁷ Calculated using the IHA software (The Nature Conservancy, 2009)



Methodology – project components



Mapping of river types onto the stream network network – new typified stream network



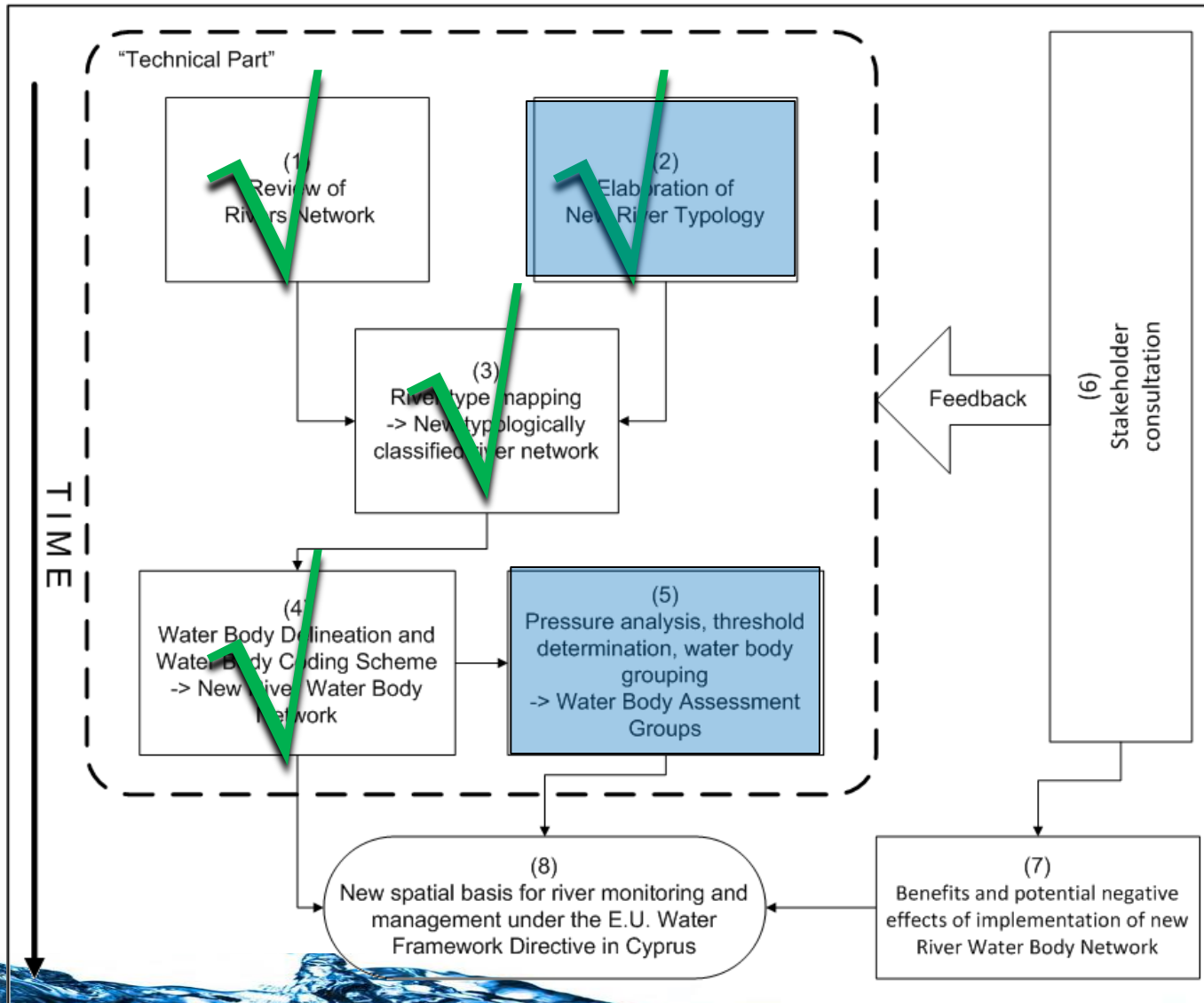
Delineation of WFD River Water Bodies

245 river water bodies (incl. 15 impounded rivers)

River type	River type name	Rivers (genuine)	Impounded rivers (Water reservoirs)	Total
P	Perennial mountain streams	30	3	33
I	Intermittent streams	64	9	73
Ih	Harsh intermittent streams	57	3	60
E	Ephemeral / episodic streams	76	0	76
No type	No type assigned due to lack of data	3	0	3
Total		230	15	245



Methodology – project components



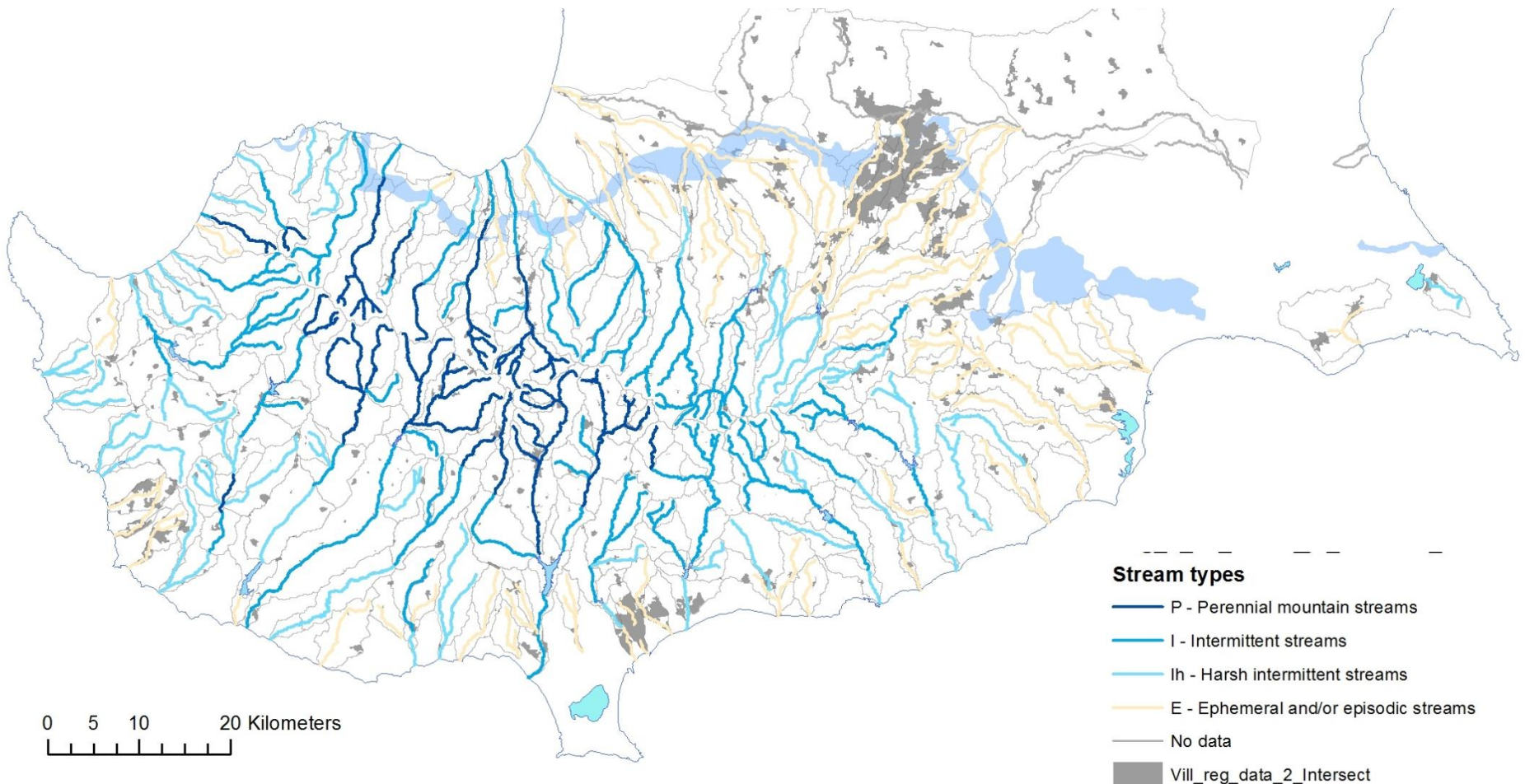
Water Body Grouping Scheme (1)

- **Aim: Predict ecological status of unmonitored water bodies, by using the data collected in monitored water bodies.**
- **Methodology – implementation steps:**
 - Identification of important pressures and corresponding pressure characteristics
 - Quantification of pressure intensities on water body level
 - Identification of relationship: ecological status vs. pressure intensities
 - Thresholds of pressure intensities corresponding to ecological status classes (negligible pressure -> high status, minor pressure -> good status, important pressure -> status worse than good)
 - Combination of different pressures into a single “Combined pressure indicator”
 - Assignment of combined pressure levels to all river water bodies



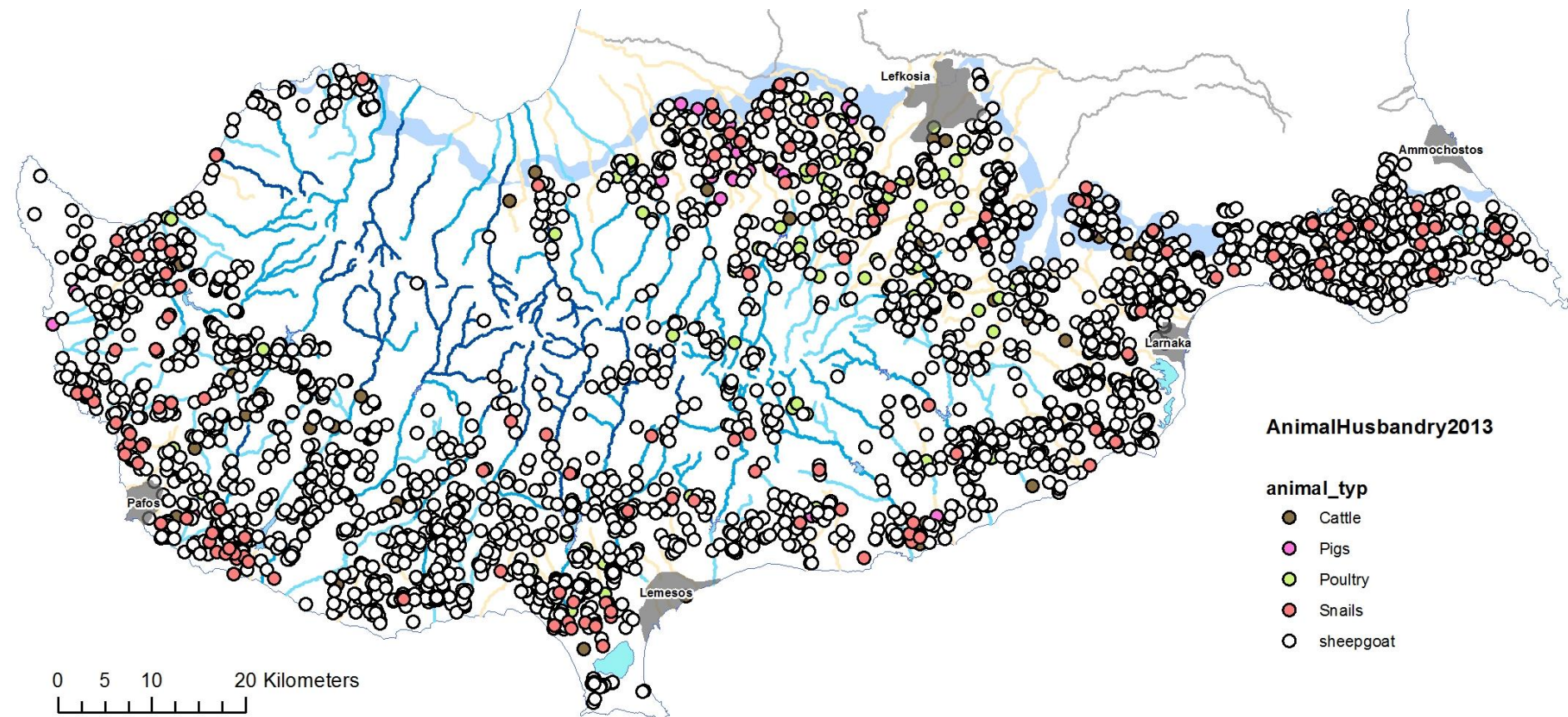
Water Body Grouping Scheme (2)

- Pressure characteristic: Population density
- CORINE 2006 level 2 class 11 “urban fabric” combined with Census 2011 (CYSTAT, 2013)



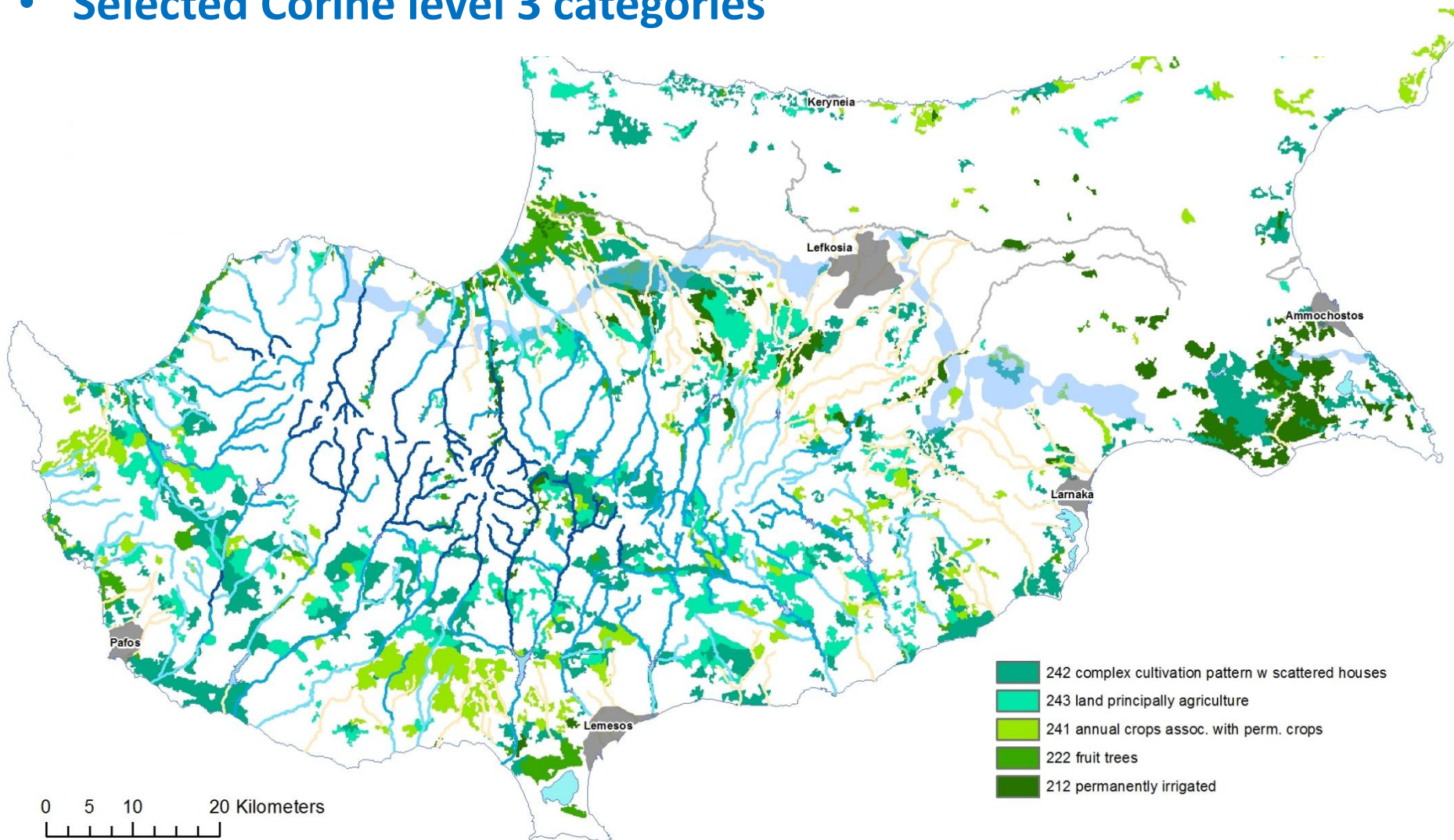
Water Body Grouping Scheme (3)

- Pressure characteristic: Livestock annual Nitrogen load
- Animal number per livestock unit (data provided by Cyprus Veterinary Services) combined with indicative loads per animal (Defra, 2009)



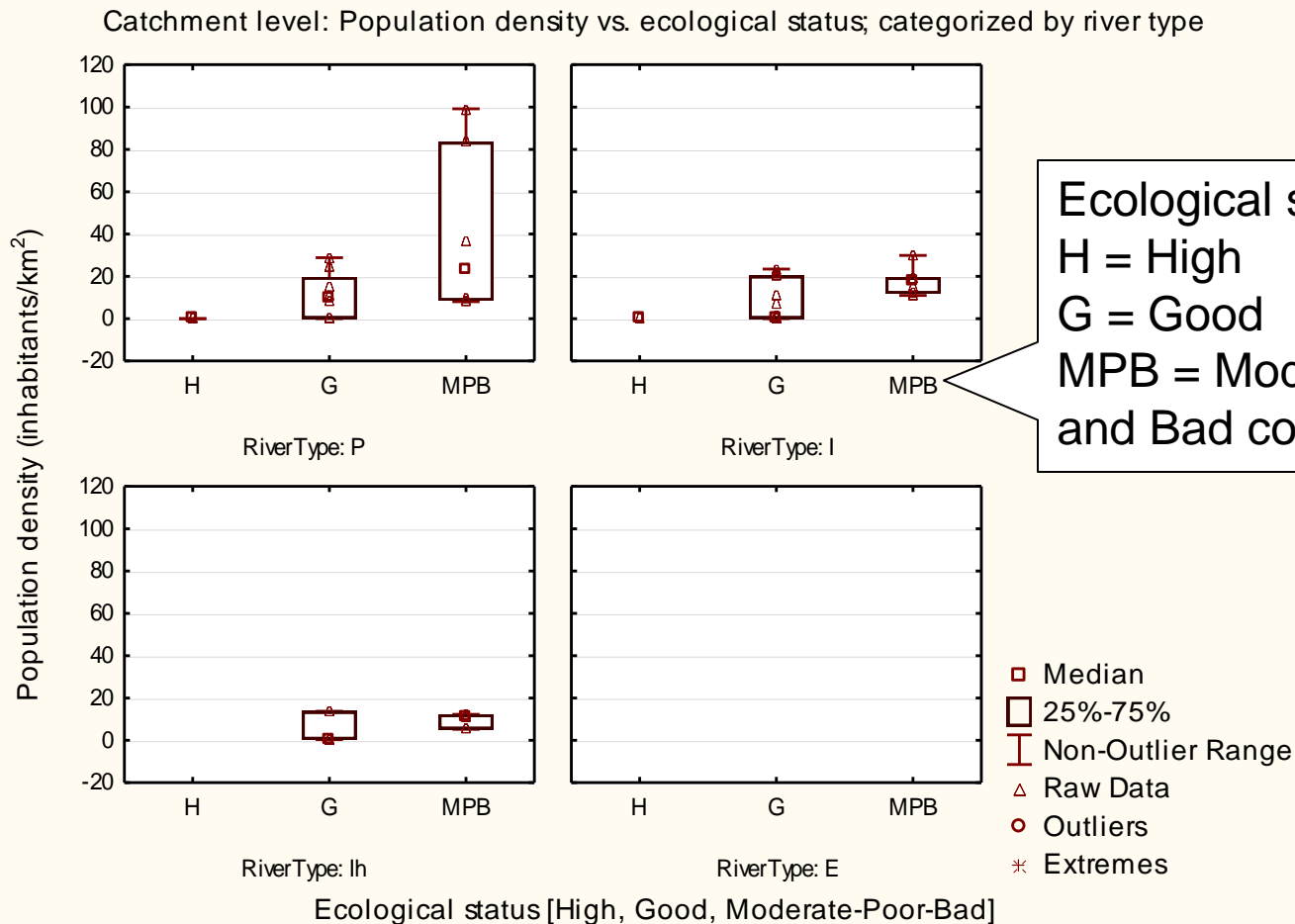
Water Body Grouping Scheme (4)

- Pressure characteristic: Areas of “intensive agriculture”
- Selected Corine level 3 categories



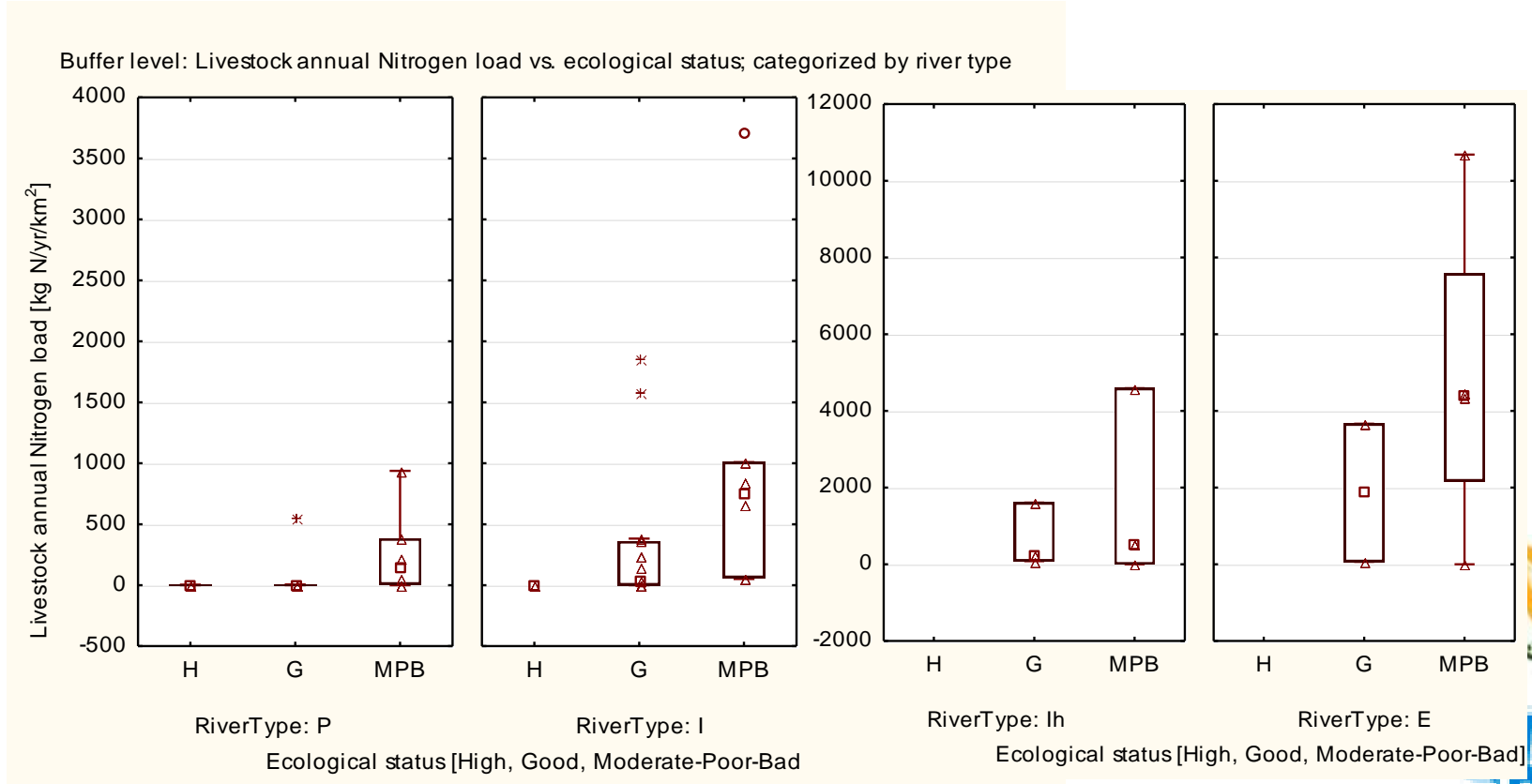
Water Body Grouping Scheme (5)

- Ecological status vs. pressure intensities (for each stream type)
- Pressure characteristic: Population density



Water Body Grouping Scheme (6)

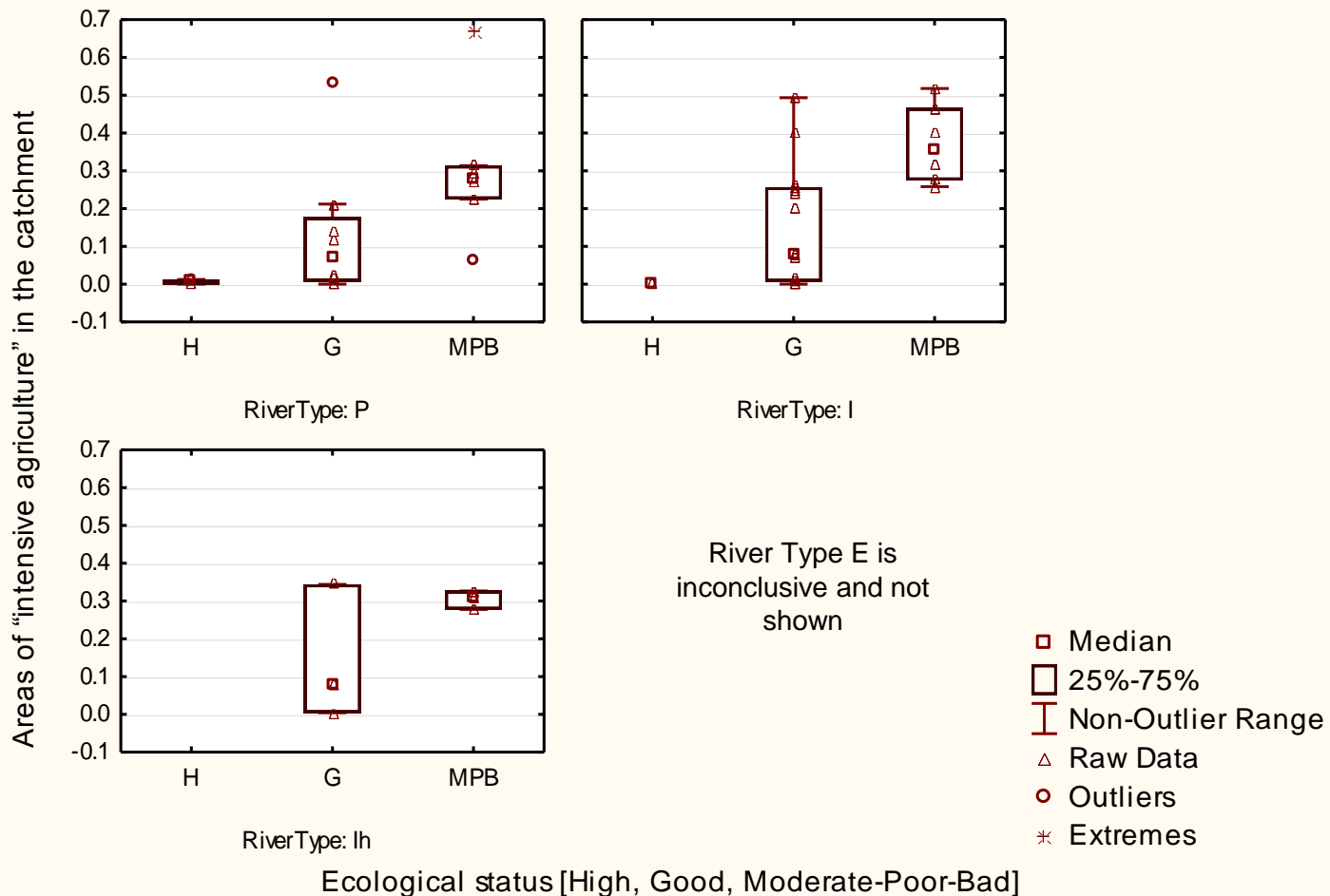
- Ecological status vs. pressure intensities (for each stream type)
- Pressure characteristic: Livestock annual Nitrogen load



Water Body Grouping Scheme (7)

- Ecological status vs. pressure intensities (for each stream type)
- Pressure characteristic: Areas of “intensive agriculture”

Catchment level: Areas of “intensive agriculture” vs. ecological status; categorized by river type



Water Body Grouping Scheme (8)

- Thresholds between pressure intensities, corresponding to ecological status class boundaries

Pressure characteristic	Threshold between pressure levels	River type			
		P	I	Ih	E
Population density [inhabitants/km ²]	Negligible /minor	0 (c)	0 (c)	-*	0** (c)
	Minor/important	14.1 (c)	16 (c)	-*	1100** (c)
Livestock annual Nitrogen load [kg N/yr/km ²]	Negligible /minor	1.9 (b)	0 (c)	0** (b)	0** (b)
	Minor/important	6.2 (b)	569 (c)	1800** (b)	4000** (b)
Areas of “intensive agriculture”, assumed to be largely irrigated [portion of area]	Negligible /minor	0.01(c)	0.007(c)	0** (b)	-*
	Minor/important	0.225(c)	0.275(c)	0.317 (b)	-*

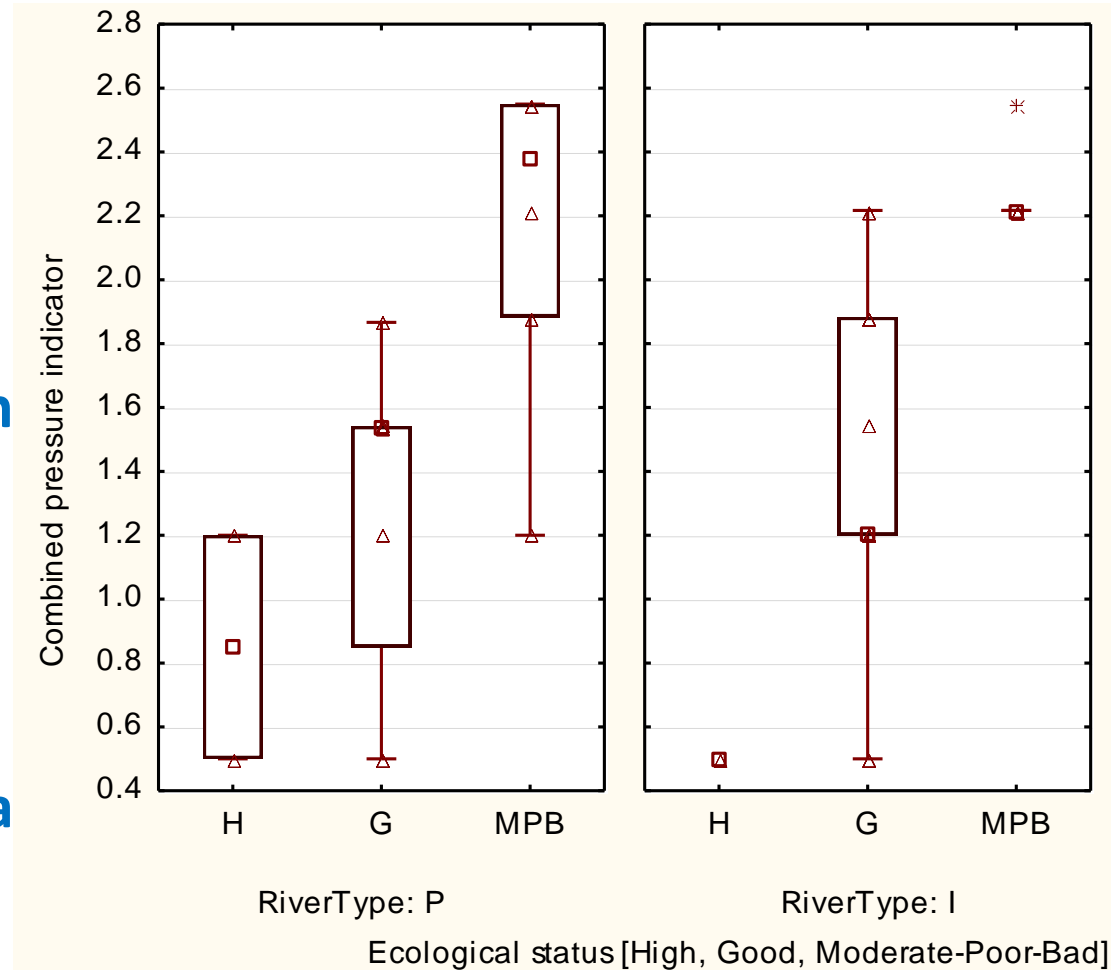
*) Pressure not used for the grouping of the water bodies of this type

**) based on expert judgement

(c) = catchment level, (b) = stream buffer level

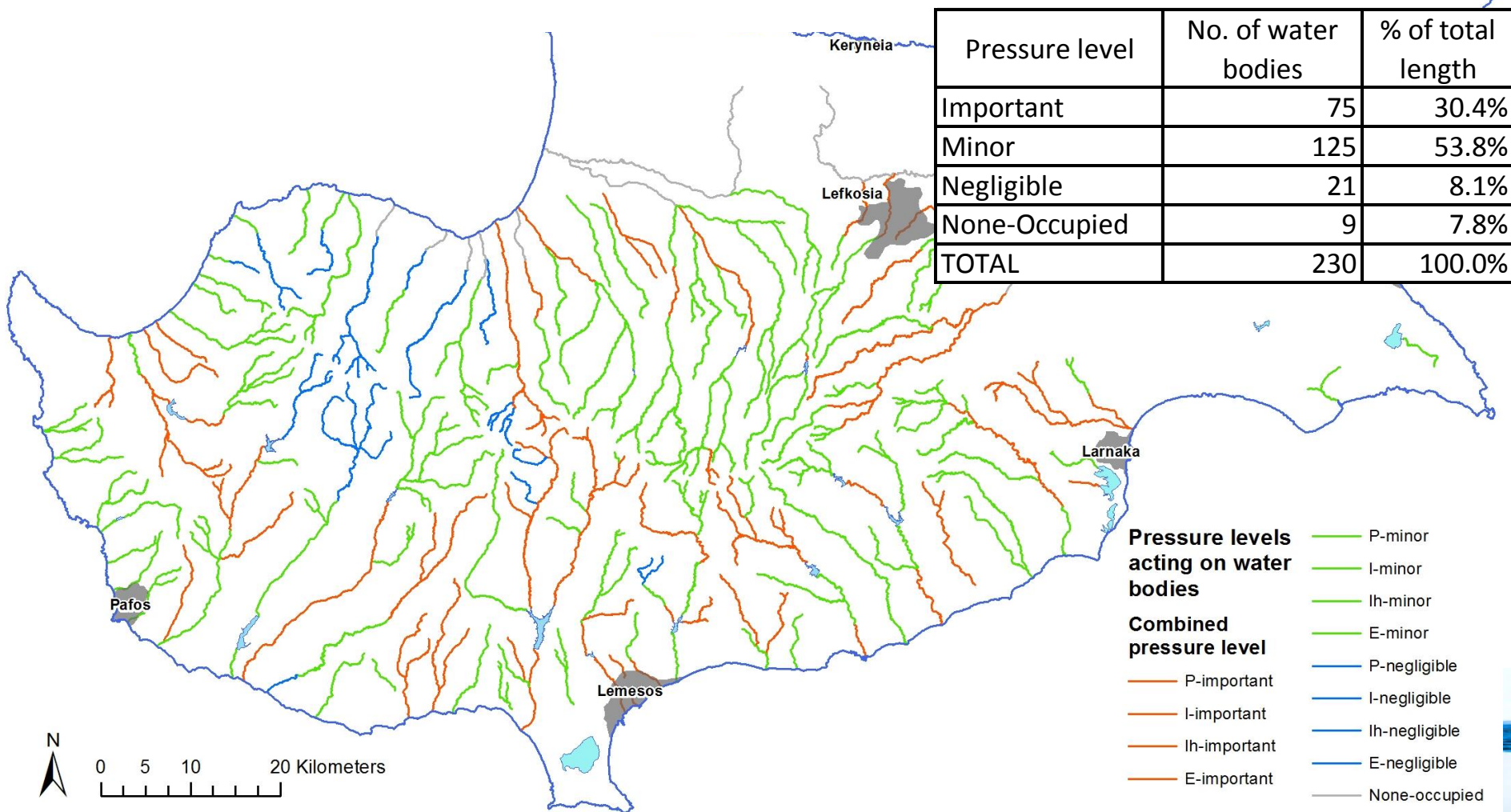
Water Body Grouping Scheme (9)

- Three pressure characteristics combined into a single “Combined Pressure Indicator” (CPI)
- Clearer distinction between status classes than for separate pressure characteristics
- “Combined Pressure Indicator” (CPI) works like a multi-metric index



Water Body Grouping Scheme (10)

- River water bodies and combined pressure levels
- 12 assessment Groups (4 stream types, 3 pressure levels)



Outcome - Results

- New river typology for implementation of the Water Framework Directive (2000/60/EC) in Cyprus
- New typified WFD water body network
- Assessment groups scheme for assessing ecological status of unmonitored water bodies
- Multi-criteria methodology for assigning stream types to ungauged stream reaches
- *The new spatial basis and other outcome are already being utilized for the elaboration of the 2nd RBMP and for the implementation of WFD monitoring programmes.*



Thank you for your attention



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