Temporary rivers in Cyprus: Overview and some specific issues

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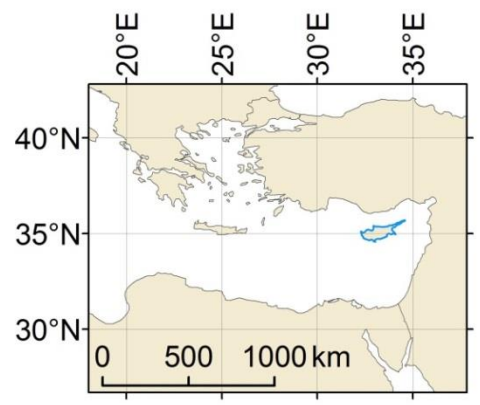
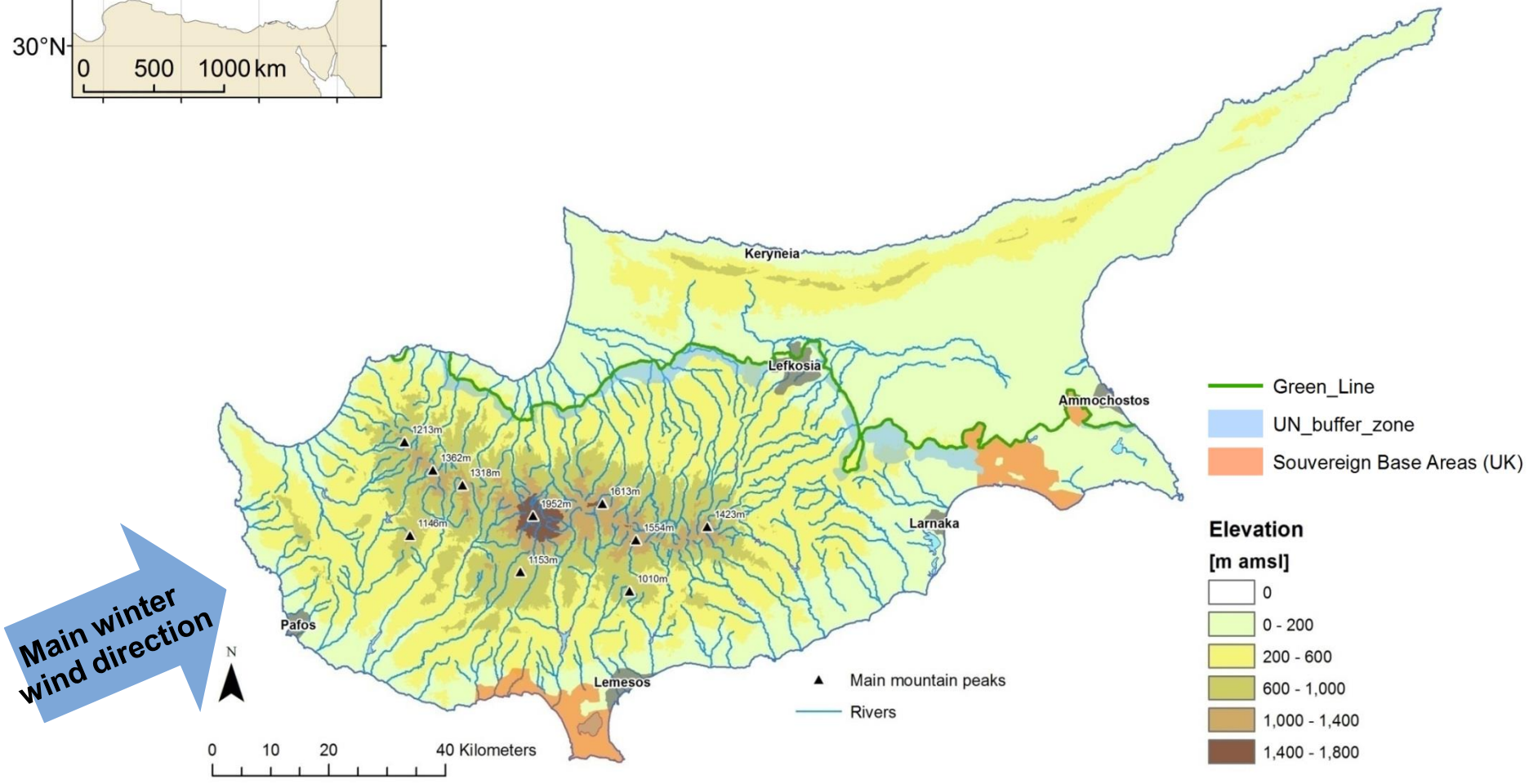
A short Cyprus overview
Topography

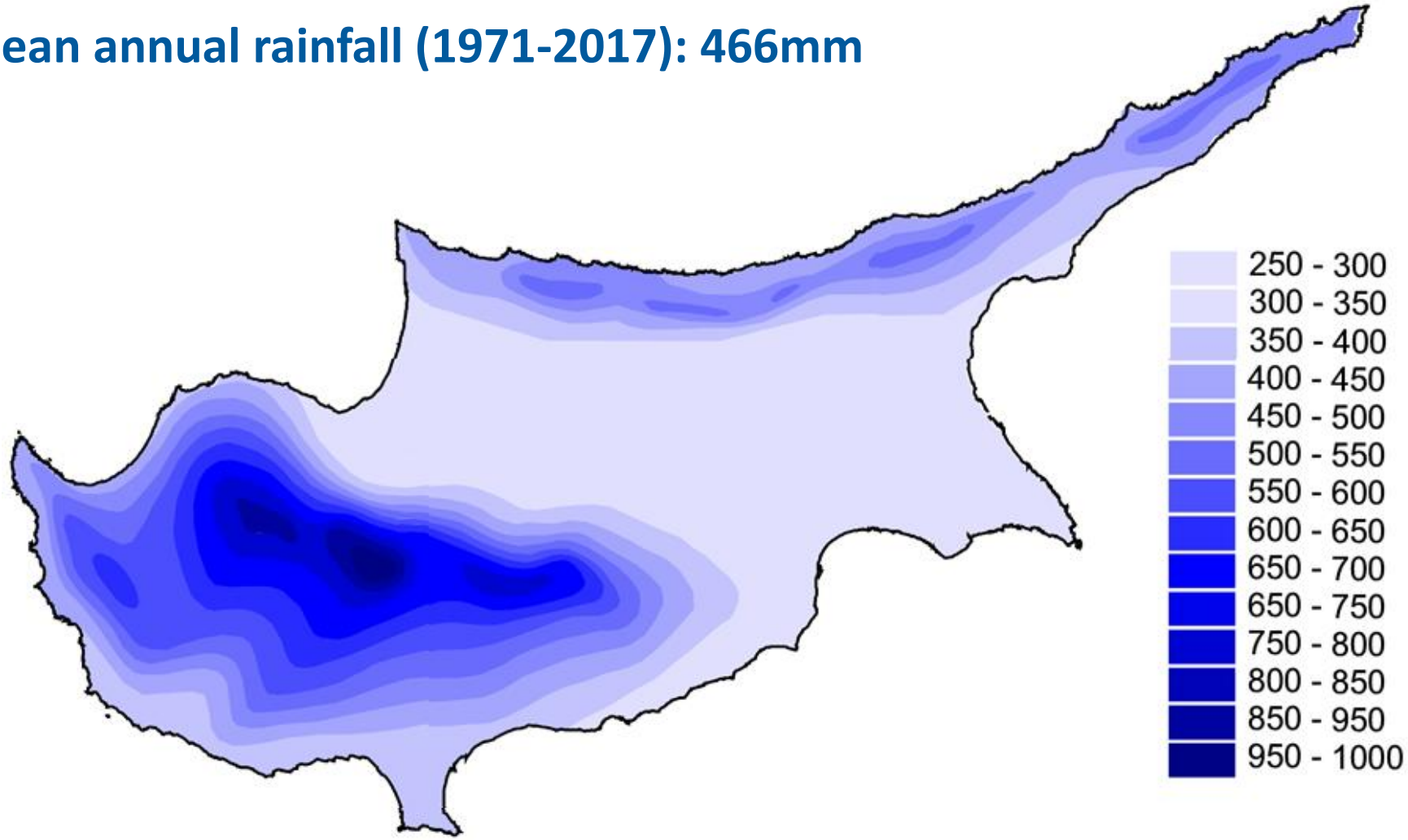




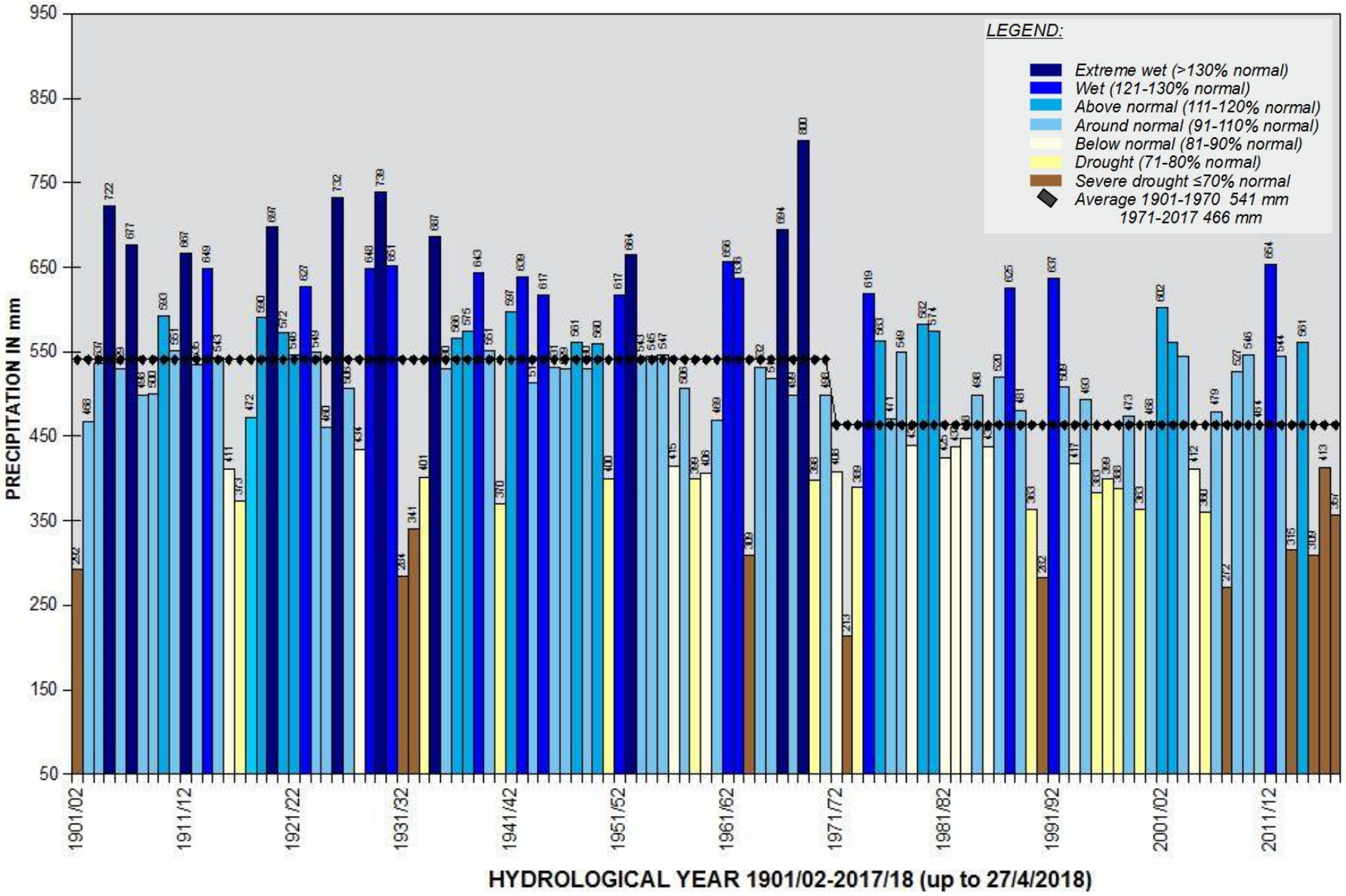
A short Cyprus overview - Annual Rainfall

Mean annual rainfall (1901-1970): 541mm

Mean annual rainfall (1971-2017): 466mm



Annual Rainfall … getting less and less



Streamflow trend analysis

- M-K test on hydrologic variables to detect possible trends
- Data from 11 flow gauges, undisturbed by artificial interventions
- 34-year common reference period (10/1979 to 09/2013)

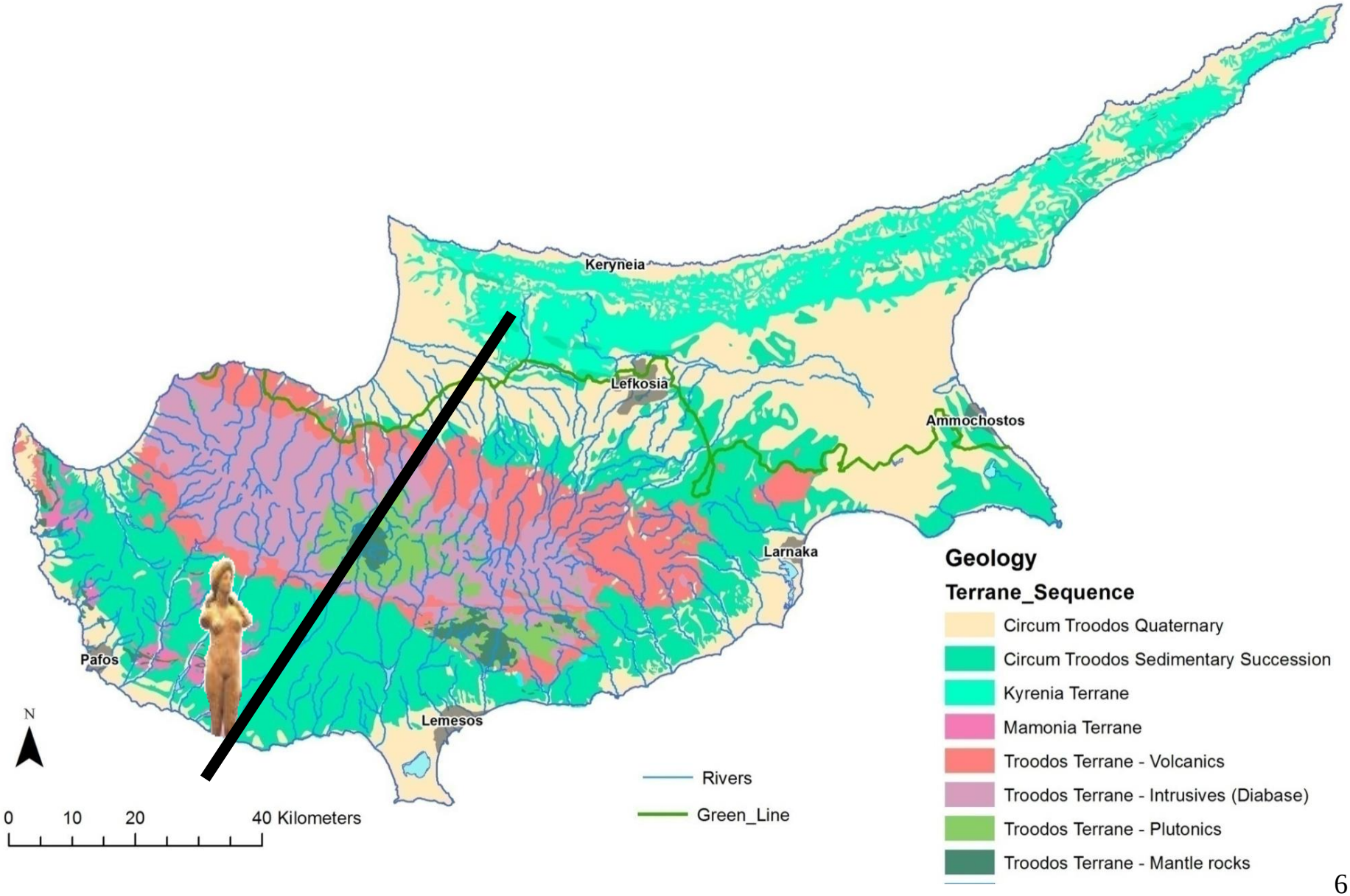
Results of the M-K test for the time series of the annual volumes

River type	P	P	P	I-P	I-P	I-P	I-P	I-P	I-D	I-D	I-D
Hydrological Region	**1**	**3**	**3**	**1**	**2**	**2**	**3**	**3**	**2**	**6**	**6**
Flow gauging station/catchment no.	**1**	**6**	**7**	**2**	**3**	**5**	**8**	**9**	**4**	**10**	**11**
Average annual streamflow volume (mcm)	**12**	**8.28**	**1.9**	**3.8**	**2.55**	**5.13**	**0.72**	**12.22**	**0.41**	**1.56**	**3.38**
Kendall's tau (τ)	−0.02	−0.15	−0.13	−0.07	−0.16	−0.15	−0.27	−0.07	−0.09	−0.13	−0.15
S	−11.00	−83.00	−73.00	−41.00	−91.00	−83.00	−151.00	−41.00	−49.00	−75.00	−39.00
p value	0.88	0.22	0.29	0.55	0.18	0.22	0.03	0.55	0.48	0.27	0.32
Sen's slope	**−11,863**	**−9708**	**−2625**	**−31,296**	**−38,726**	**−62,577**	**−16,810**	**−76,511**	**−3563**	**−13,278**	**−60,161**
Reduction/decade %	**−0.99**	**−1.17**	**−1.38**	**−8.23**	**−15.17**	**−12.21**	**−23.25**	**−6.26**	**−8.69**	**−8.50**	**−17.79**

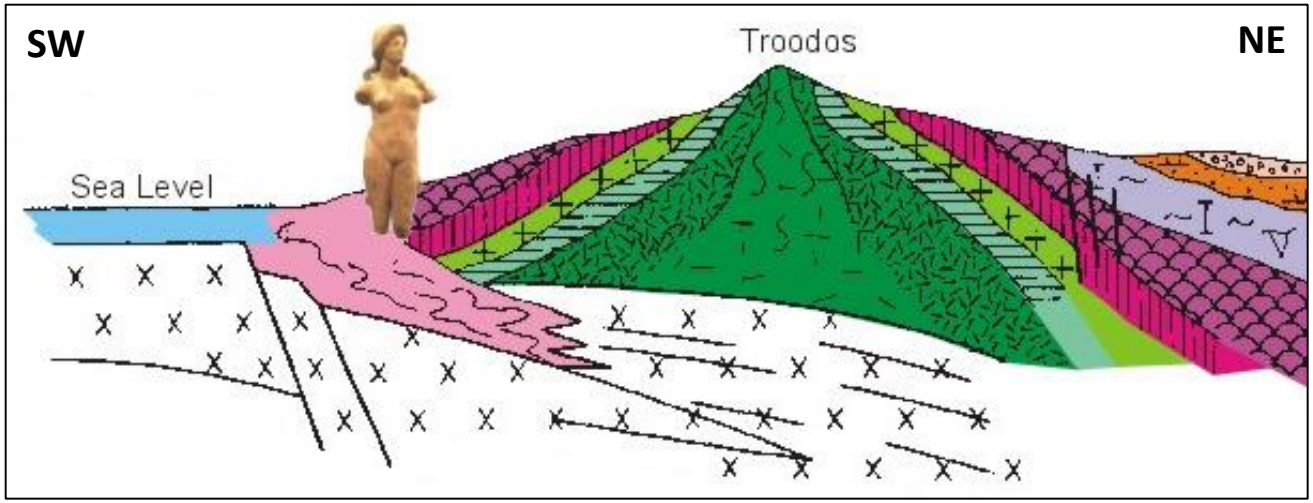
(Myronidis et al., 2018)

- S-statistic negative in all cases → decreasing trend, not significant
- Sen's slope to compute size of reduction per decade → reductions greater in intermittent (6-23%) than in perennial reaches (around 1%)

A short Cyprus overview - Geology

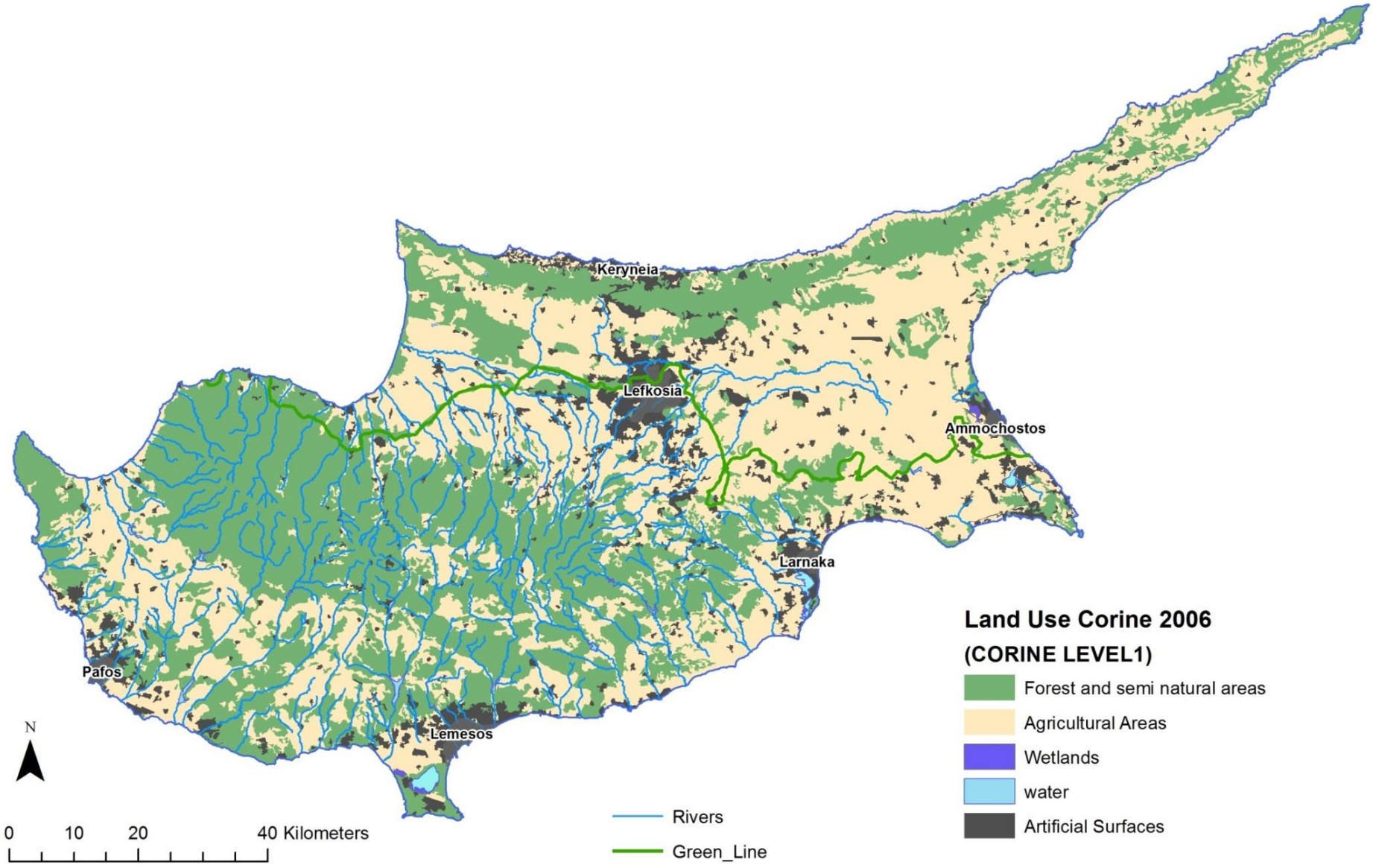


A short Cyprus overview – Geology



Source: Cyprus Geological Survey Department (modified) http://www.moa.gov.cy/moa/gsd

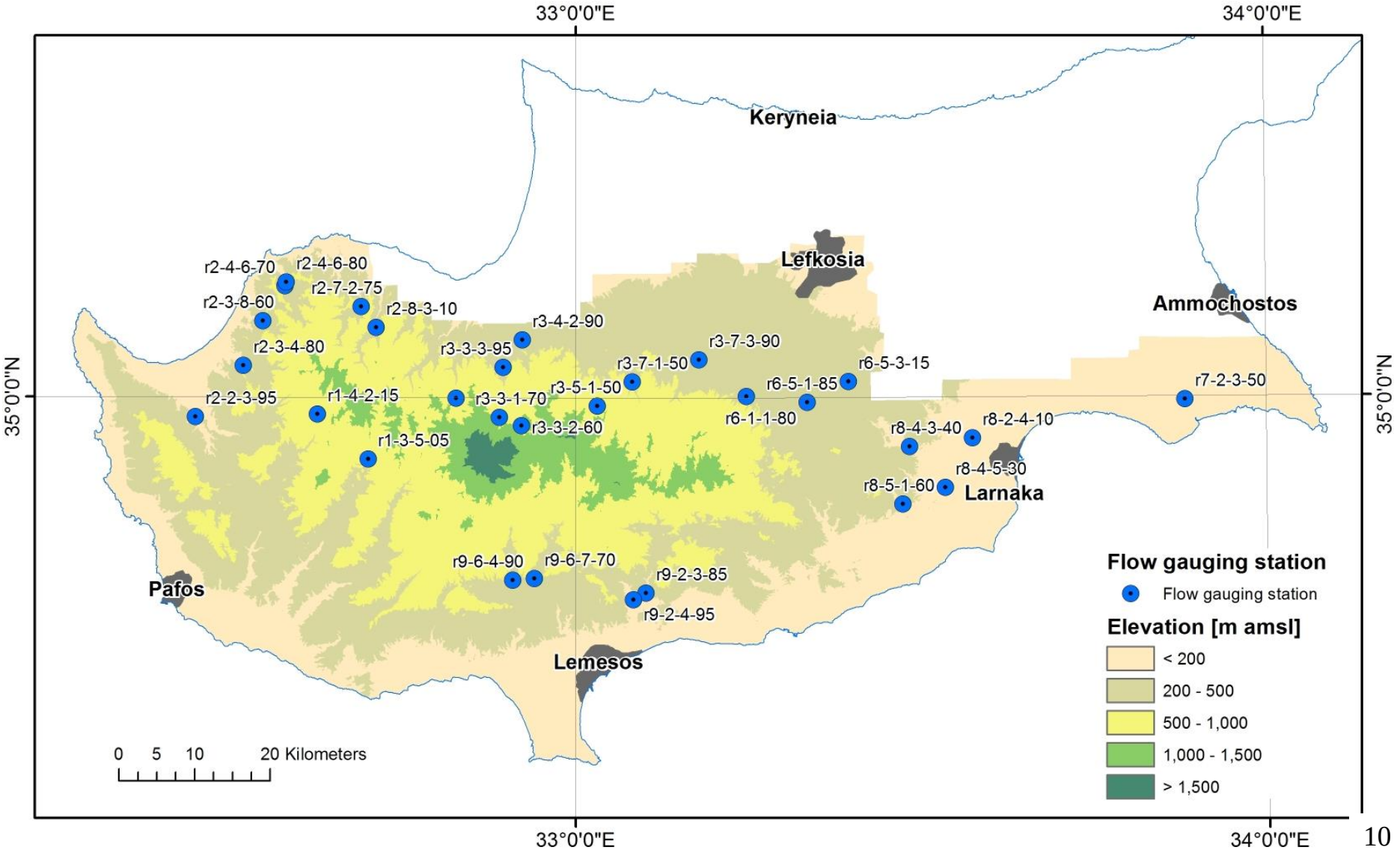
A short Cyprus overview – Land Use (as a proxy for pressures)



River Typology (new typology for the 2nd RBMP)

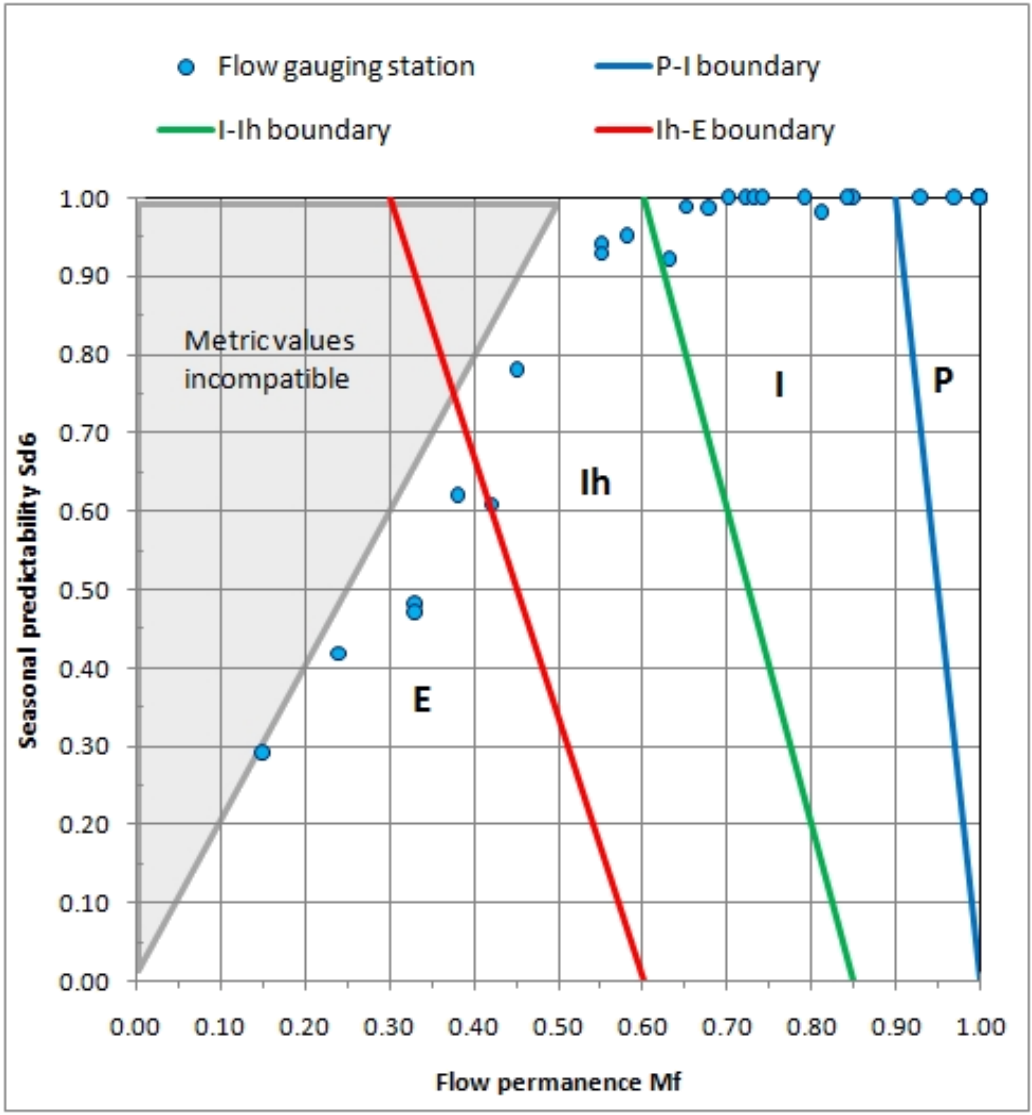
- 1st River Basin Management Plan (2009): Temporary rivers were included in the typology, but there was a lack of knowledge of the different types of temporary rivers.
- Decision to develop a new river typology for the 2nd RBMP.
- Adopted method for new typology: Temporary Stream Regime Tool (Gallart et al. 2012)
  - Four stream types (flow regimes): Perennial, Intermittent-Pools, Intermittent-Dry, Ephemeral-Episodic
  - Stream types directly relate to the relevance of biological communities for WFD monitoring purposes (i.e., *ephemeral/episodic rivers cannot be assessed, at least with currently available methods*)
- Input data: recorded stream flow data from 29 Cyprus gauges
- New typology was complemented by a review of the "identification of water bodies", new mapping of river types, new water body delineation.

Flow gauging stations for the new river typology



TSR-plot with data from 29 flow gauging stations

- Data covers the whole range of flow regimes from perennial to ephemeral/episodic
- Distinctive alignment of the plotting positions along a gradient

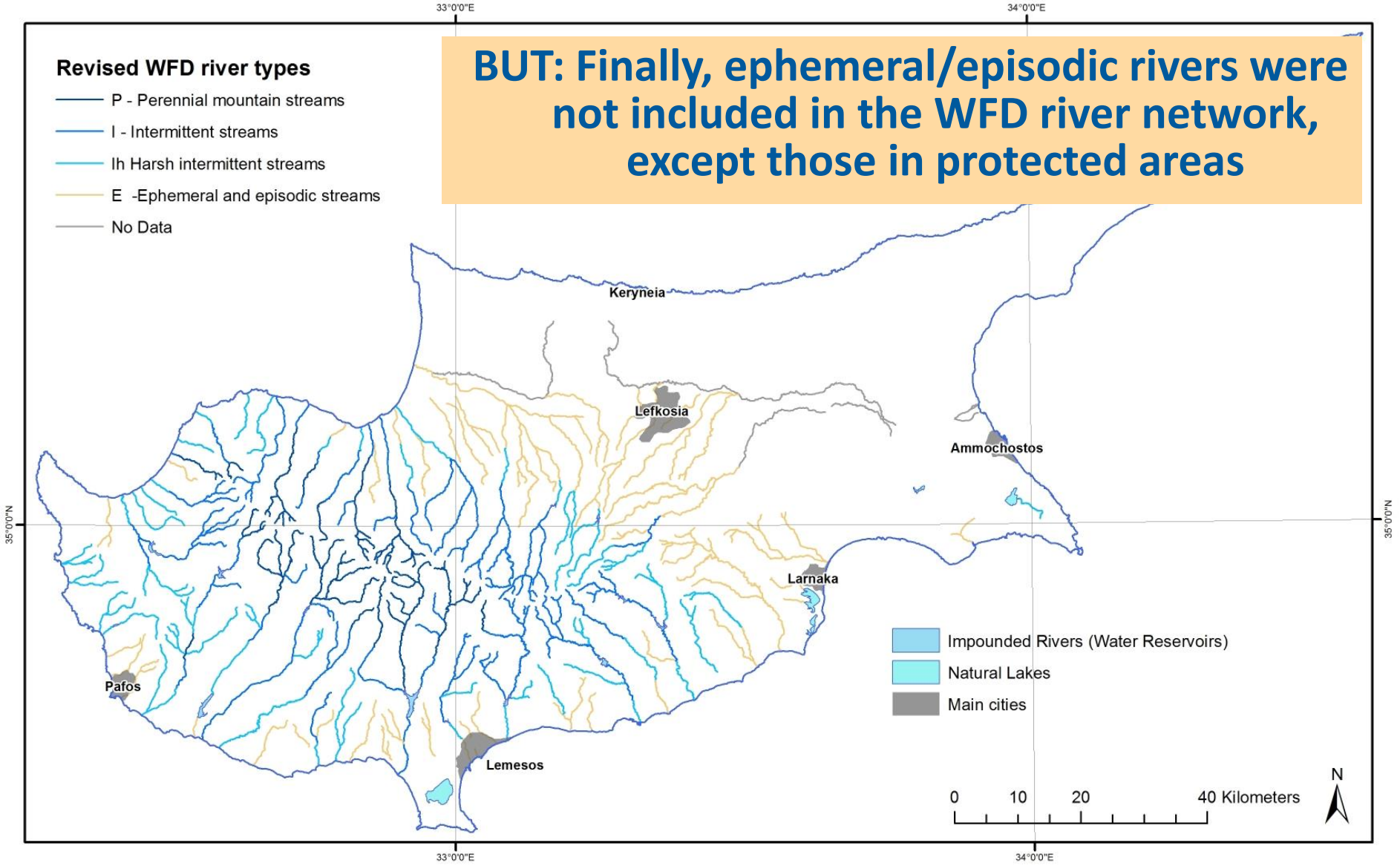


New Cyprus river typology for the 2nd RBMP Hydrological & flow regime characteristics

Type code	River flow category (TSR regime[3])	Type name	Mean annual flow [m³/s]	Specific catchment yield [L/s/km²]	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)

New typology mapped on the stream network



Treatment of ephemeral/episodic streams (1)

1) Guidance Document No. 2 “Identification of water bodies”:
   a) The main purpose of identifying “water bodies” is to enable the status to be accurately described and compared to environmental objectives.
   b) A “surface water body” comprises the quality elements described in the Directive for the classification of ecological status i.e. principally the BQEs.
2) For ephemeral rivers, "*other methods beyond the usual study of aquatic fauna*" are needed and "*these methods are not yet available*" (Gallart et al. 2012). Thus, it is virtually impossible to measure the WFD BQEs in ephemeral rivers with current / available methods.
3) Based on (1) and (2) above, ephemeral rivers were assessed as not relevant under the Water Framework Directive, except where they are in connection with important ecosystems i.e. protected areas (Habitats & Birds Directives).

Treatment of ephemeral/episodic streams (2)

4) Ephemeral rivers are protected from pollution and from anthropogenic interventions by Cyprus' national legislation

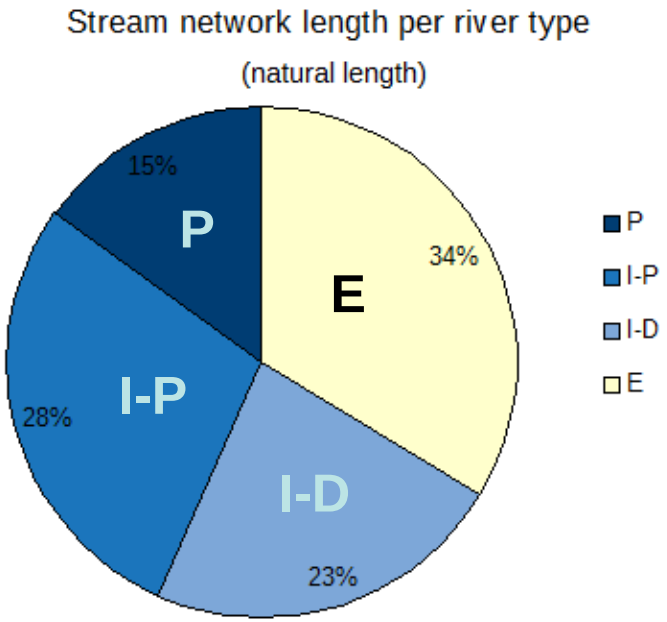
5) For all ephemeral streams, irrespectively whether they are WFD WBs or not:

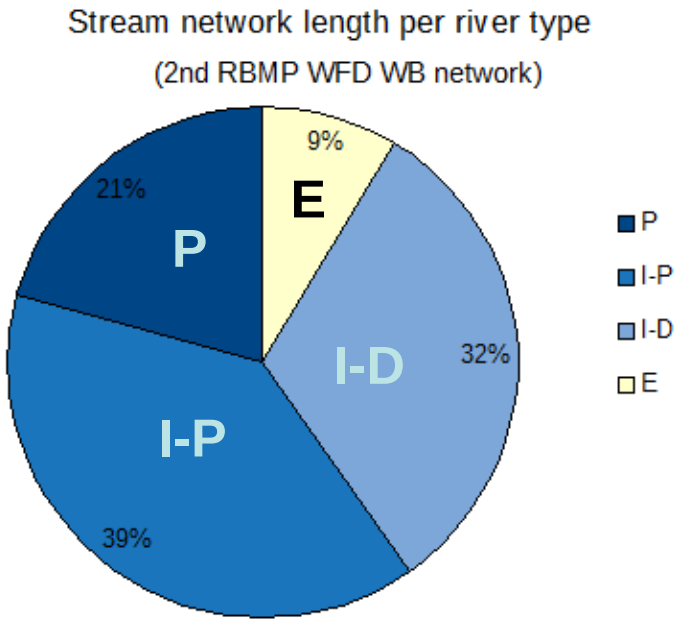
   a) A specific measure has been included in the Program of Measures to monitor their physico-chemical and chemical quality

   b) Pressures in ephemeral catchments and their impacts are assessed in downstream groundwater bodies and coastal water bodies, respectively in downstream river water bodies in the case of ephemeral tributaries.

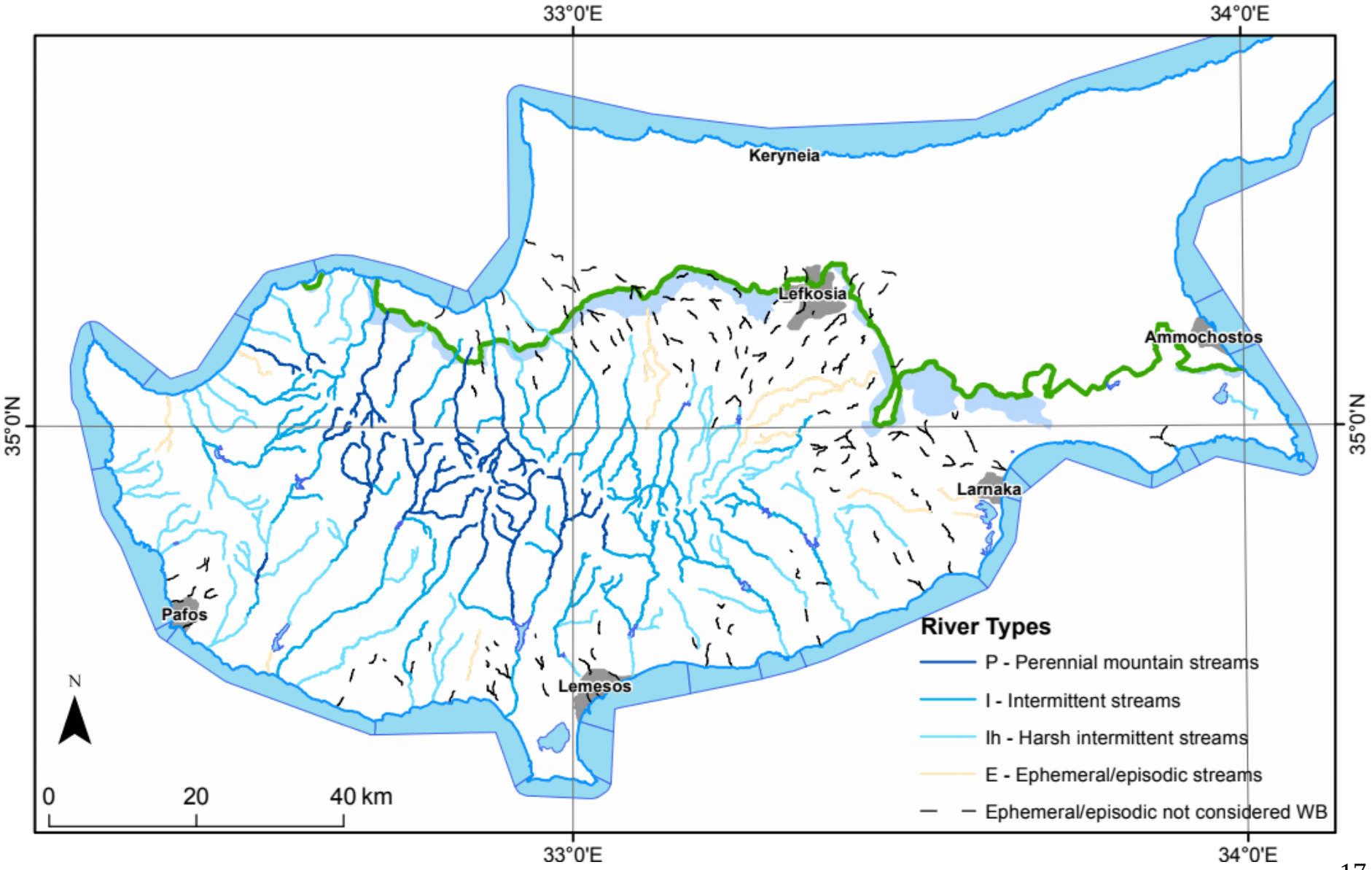
Cyprus river water body network (2nd RBMP)

River type	P	I-P	I-D	E	Total
Natural length [km]	369.0	692.1	563.5	825.5	2450.1
% of total natural length	15%	28%	23%	34%	100%
WFD WB network length (km)	369.0	692.1	563.5	152.5	1777.2
% of WFD WB network length	21%	39%	32%	9%	100%
Number of WFD river water bodies	30	62	56	11	159





Cyprus river water body network (2nd RBMP)



WFD river monitoring network (3rd monitoring cycle)

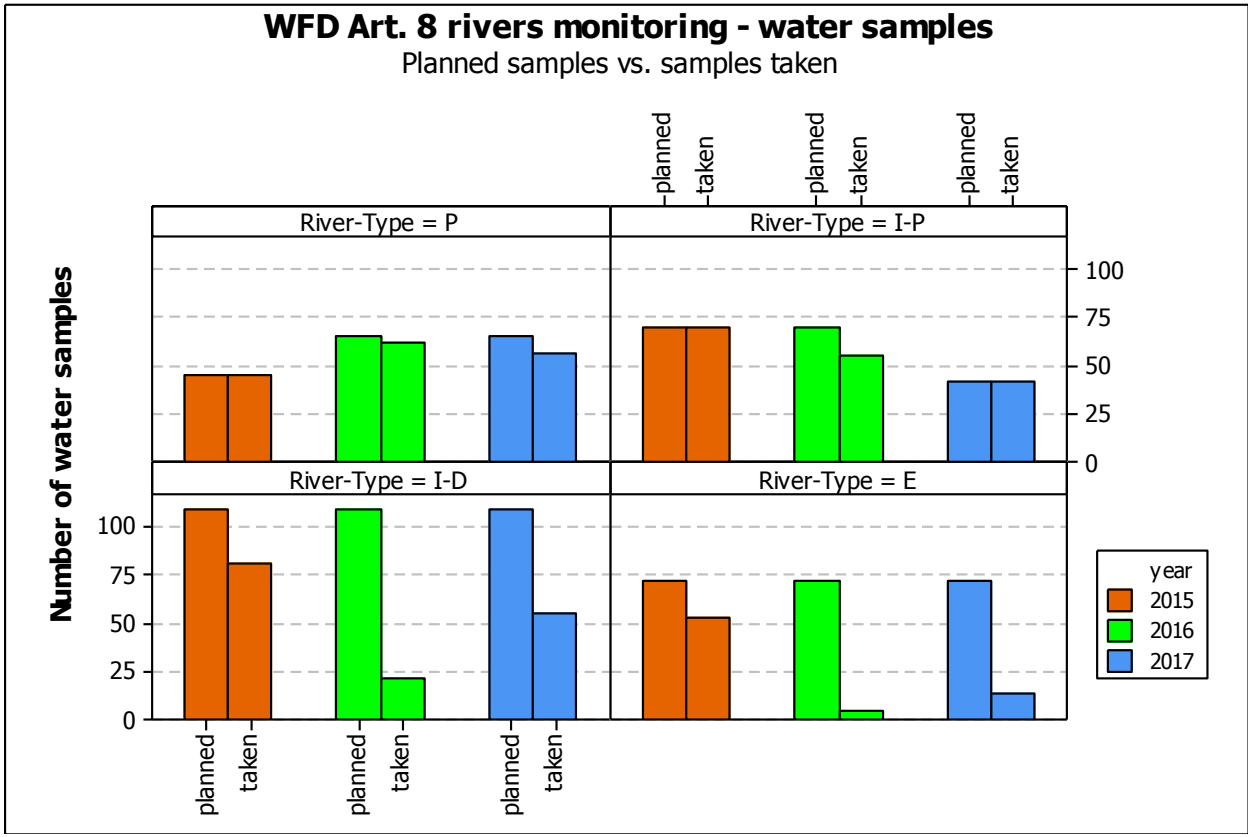
- **Number of monitoring stations per river type:**

River type → Quality element ↓	**P**	**I-P**	**I-D**	**E**	**Total**
Ecological Status - Biological Quality Elements (MPH, PB, MINV)	23	22	25	-	70
Ecological Status – supporting chemical & physico-chemical elements	23	22	25	24	94
Chemical Status Directives 2008/105/EC, 2013/39/EU	14	13	13	16	56

- **Monitoring stations on I-D and E type rivers are in the program every year for all applicable QEs**
- **Operational (due to bad chemical status) monitoring stations are sampled every year for the failing parameters**
- **Monitoring stations on P and I-P type rivers are usually monitored in 2 or 3 years of one 6-year monitoring cycle, depending on the pressure level**

Impact of inter-annual flow variability on water sampling in Cyprus' temporary rivers

- Recall rainfall 2015-2017:
  - 2015: above average 561mm
  - 2016: severe drought 309mm
  - 2017: severe drought 413mm
- High impact on I-D and E types, even in above average rainfall year
- Different impact 2016 vs. 2017 on all temporary types
- Low impact on I-P type



Experiences with the new river typology

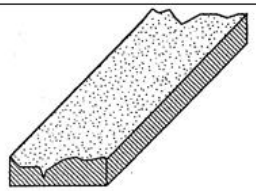
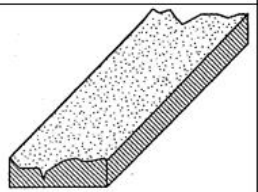
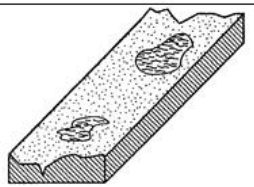
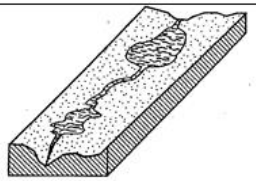
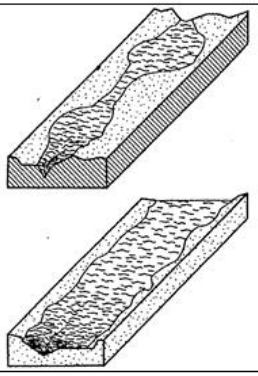
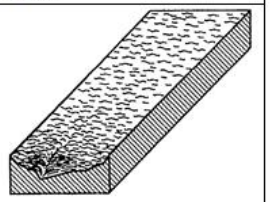
+ **Distinction between the different temporary river types has many benefits**
+ **Type-targeted assessment and management becomes possible**
+ **Monitoring can be planned with higher certainty and efficiency**
- **Wrong type assignments have been identified:**
  - **Mostly because of local geological conditions (springs)**
  - **Because of insufficient coverage of some areas/cases with reference stations**
  - **There is a need to improve stream type mapping**

Improving the mapping of temporary rivers (for the 3rd RBMP)
Aquatic State monitoring

- Aquatic state: Observation in the field is quick and easy
- Aquatic state is monitored along with stream flow at all Cyprus stream gauging stations and at all spot-measurement stations by now
- In some stations, aquatic state only is monitored – without stream flow, but it is sufficient to determine the TSR flow regime of a monitoring site.
- Objectives:
  - To provide knowledge about the low flow and no-flow periods in Cyprus rivers
  - To aid in improving the stream type mapping for the 3rd RBMP
  - To determine flow thresholds between the different aquatic states

Aquatic State "definitions" used in Cyprus

Descriptions and images as guidelines for technical staff to correctly identify aquatic state:

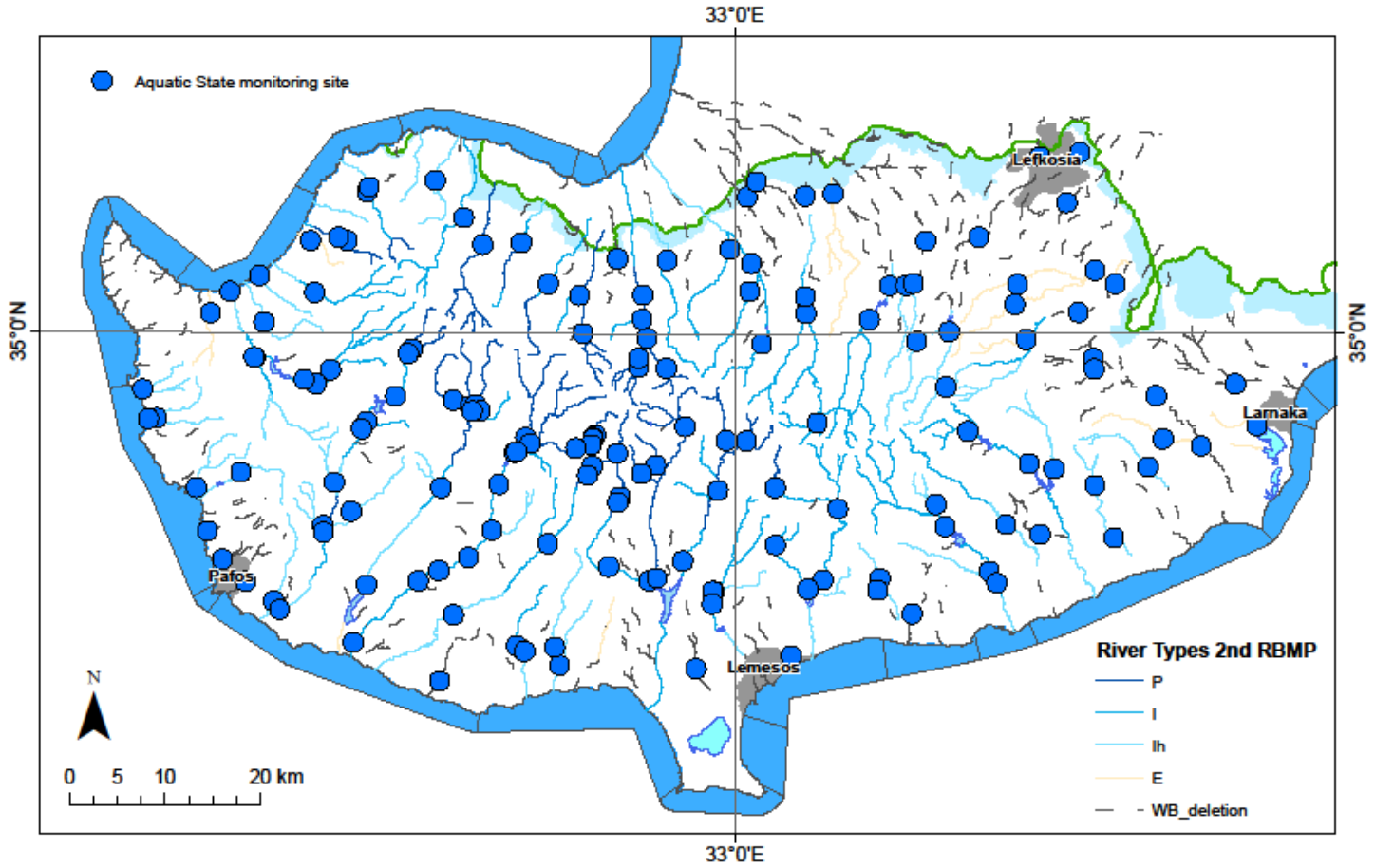
Aquatic State[1]	edaphic	hyporheic	arheic	oligorheic	eurheic	hyperrheic
Numerical Code	0	1	2	3	4	5
Description[1]	The entire stream bed is devoid of surface water and the river gravels are dry. If there are plants in the river bed, they are terrestrial plants. There are no signs of river flow in the last few weeks (one month)	Most of the stream bed is devoid of surface water, although river gravels remain wet (difference to 2: no pools present). This situation last for few weeks after a flood has passed and flow and pools have disappeared.	Surface discharge is null or close to zero, but a number of water pools remain in the stream bed	Water discharge is low but sufficient to connect most pools in the reach through water rivulets. Riffles are absent or there are very few only.	Typical situation in rivers with permanent flow and the one with the widest range of discharge in intermittent rivers. Flows remain within the banks. A sequential series of gravelly shallow parts with high velocity (riffles) and pools is the norm. Plenty of Riffles.	Infrequent high water level (flood). Water levels exceed the upper edge of the bank, overflowing into the flood plain.Flow floods perennial shrubs or trees. Such water level is observed (or exceeded) once every 1-2 years. Riffles and pools non-existent or very rare.
Image[2]						

1) Gallart, F. et al. (2012), modified

2) Shannon, J., Richardson, R. and Thornes, J. (2002), modified

Aquatic state monitoring network

- Currently about 150 sites, monitored monthly
- Addition of new sites preferably:
  - in water bodies without river flow data
  - along existing routes of monitoring teams, wherever feasible



… some comments on the TSR tool

- For Cyprus, it works very well
- It is simple but captures much of the significant characteristics of temporary rivers (i.e., how long? how predictable?)
- The four types can easily be explained to stakeholders, to the public
- From Cyprus experience, "intermittent-pool" type rivers do completely dry over summer.
- Distinction between I-P and I-D types:
  - From an status assessment point of view, their distinction would not be needed – so far, the same intercalibration results apply (*but: are reference conditions the same? Too few sites in Cyprus to find out!*).
  - From a practical monitoring planning point of view, their distinction is imperative in Cyprus, because I-D streams are much less predictable. While I-P streams flow every year, I-D streams may not flow at all in drought years.

Thank you for your attention

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