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WATER RESORCES AND HYDROLOGICAL DROUGHT – CURRENT TRENDS AND FUTURE PROJECTIONS

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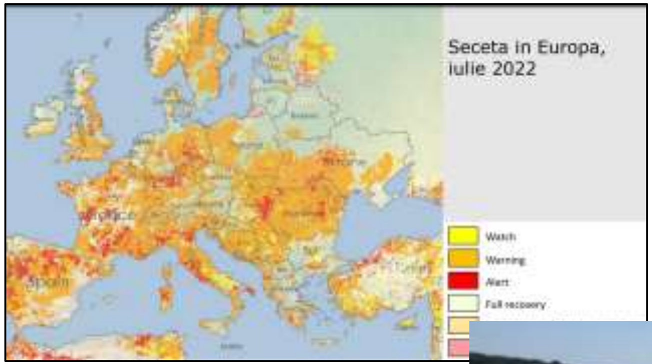
The WATER – essential element

- **Water represent a risk factor both through its lack and excess amount. The balance between these two situations can only be achieved through the proper water management, based on hydrological knowledge, monitoring of water resources, methodologies and applications resulting from research and development.**
- **In Romania, the hydrological regime of surface water and groundwater generate numerous challenges for their management.**



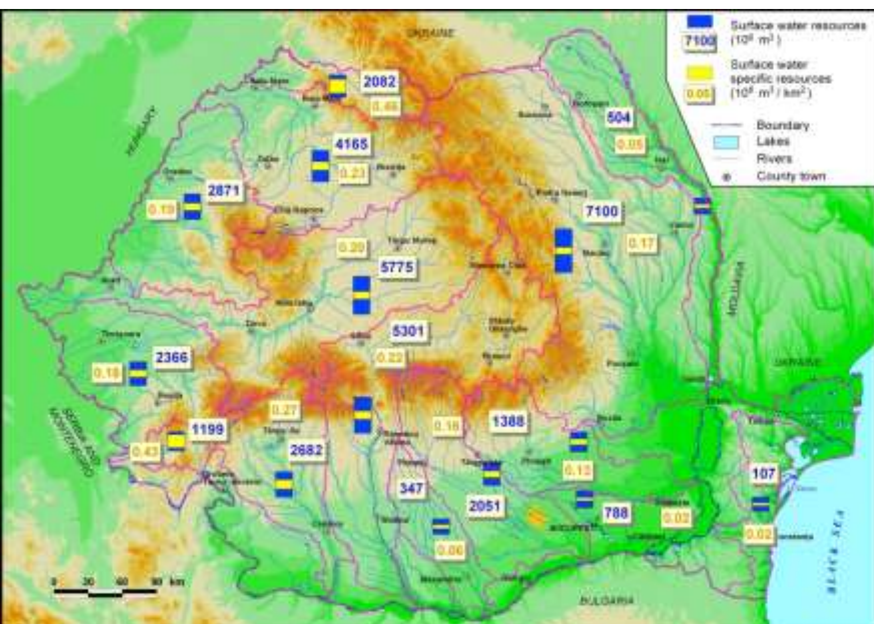
Drought in July 2022

Water Law:

- **Water is a renewable, vulnerable and limited natural resource, an unreplaceable element for life and society...**
  - ✓ **Water is a natural heritage that must be protected, treated and defended, being a strategic resource for national safety and security.**

Water resources in Romania

- The water resources of the internal rivers are about 40 billion m³/year, which represent approximately 20% of the total water resource of the Danube River.
- The river flow is different from one year to another and from region to region because of the climate factors' variation and of the great diversity of other physical-geographic factors.
- Romania has a specific water resources coming from the inland rivers of 2000 m³/inhabitant/year, occupying the 13th place in Europe.



Water resources in Romania

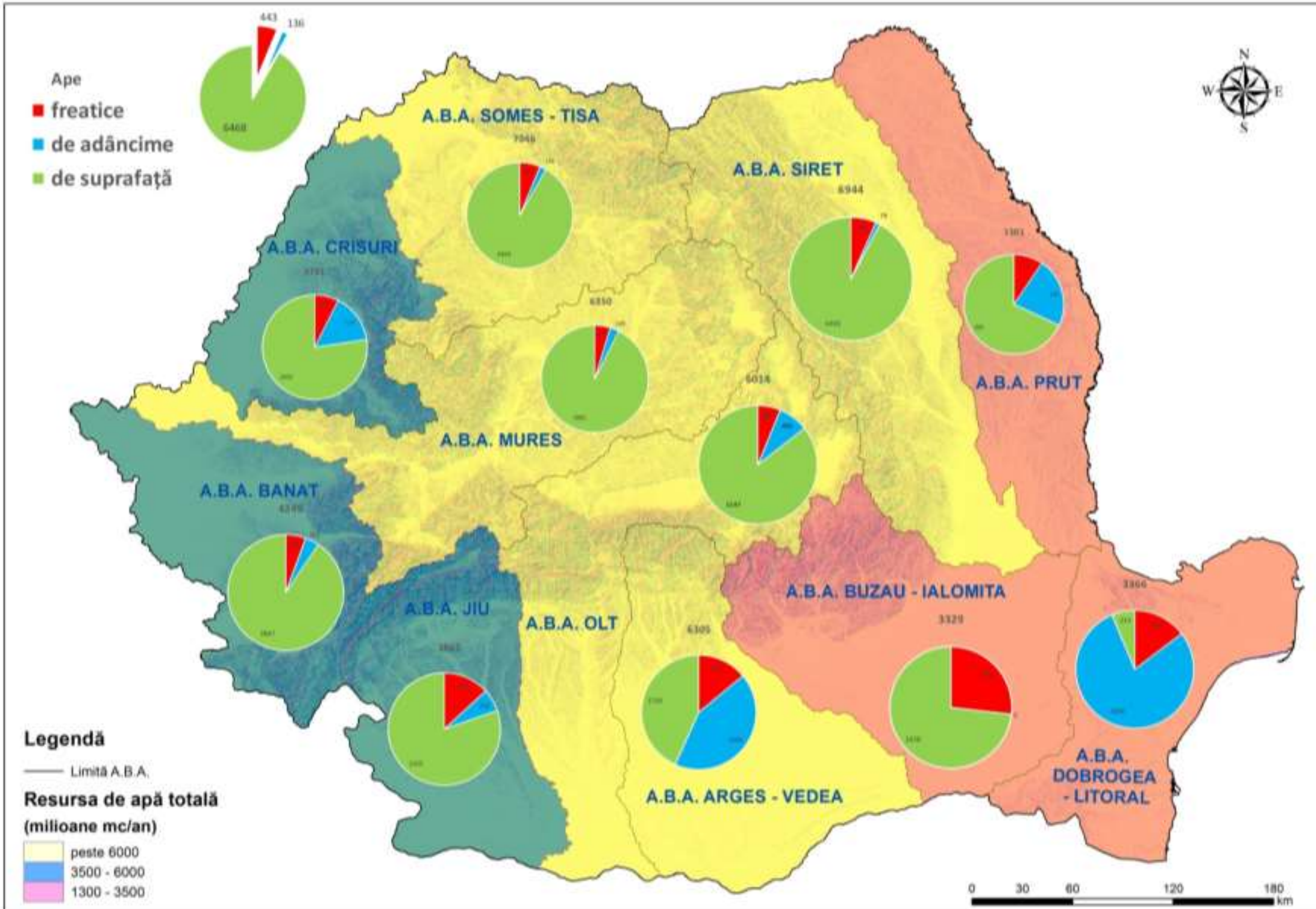
Resource category	Theoretical resource (billion m³/ year)	Technically used resource (billion m³/ year)
Inland rivers	40.0	14.1
Danube	85.0	20.0
Ground waters	10.3	6.0

General data for surface water resource

- **The long-term water resources at the WBA level, without taking into account the Danube, amount to 40,000 million m³, a discharge of 1,269 m³/s and a specific runoff of 5.3 l/s/km².**
- **The richest water resource is formed in the north of the country.**

A.B.A.	F (km^2)	Q_{med} multianual (m^3/s)	q multianual (l/s/km^2)	W_{med} multianual (10^{9}m^3)	W_{med} multianual / F (10^{6}m^3/km^2)	W_{med} A.B.A./W $_{total}$ România (%)
SOMES - TISA	22444	205.1	9.1	6.47	0.29	16.2
CRISURI	14942	92.2	6.2	2.91	0.19	7.3
MURES	28525	186.5	6.5	5.88	0.21	14.7
BANAT	18324	122.0	6.7	3.85	0.21	9.6
JIU	16775	98.4	5.9	3.10	0.18	7.8
OLT	24945	163.2	6.5	5.15	0.21	12.9
ARGES-VEDEA	21928	86.5	3.9	2.73	0.12	6.8
IALOMITA-BUZAU	24453	77.3	3.2	2.44	0.10	6.1
SIRET*	28646	203.0	7.1	6.40	0.22	16.0
PRUT-BARLAD	19927	28.1	1.4	0.89	0.04	2.2
DOBROGEA-LITORAL	17482	6.8	0.4	0.21	0.01	0.5
TOTAL ROMANIA	**238391**	**1269.0**	**5.3**	**40.02**	**0.17**	**100.0**

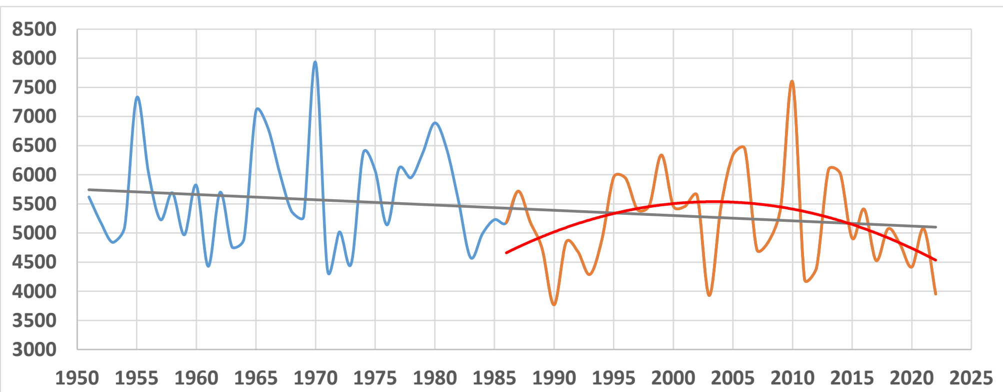
Danube - Bazias (upper Romanian sector)	**801463**	**5460.0**		**172.19**	**0.21**	
Danube (Isaccea) - entrance into danube Delta	**801463**	**6610.0**		**208.45**	**0.26**	

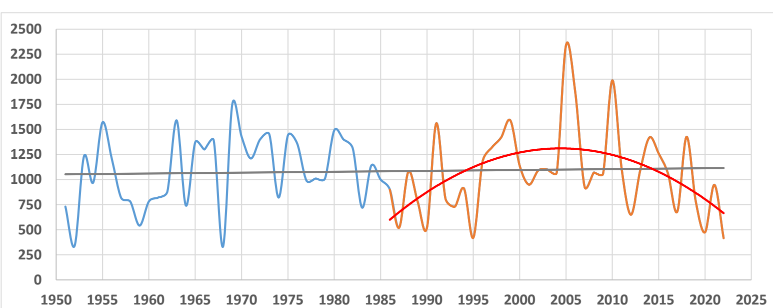


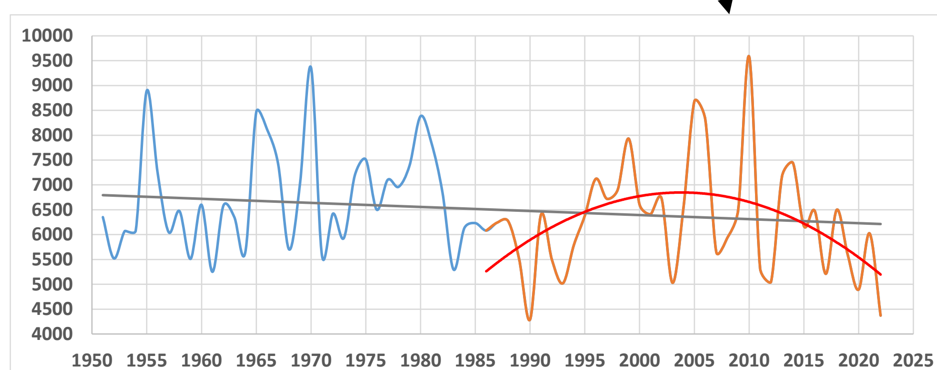
Ape
freatice
de adâncime
de suprafaţă
443
136
A.B.A. SOMES - TISA
A.B.A. SIRET
6944
A.B.A. CRISURI
A.B.A. PRUT
A.B.A. MURES
A.B.A. BANAT
A.B.A. JIU
A.B.A. OLT
6305
A.B.A. BUZAU - IALOMITA
3329
3366
A.B.A. DOBROGEA - LITORAL
A.B.A. ARGES - VEDEA
Legendă
Limită A.B.A.
Resursa de apă totală
(milioane mc/an)
peste 6000
3500 - 6000
1300 - 3500
N
S
W
E
0
30
60
120
180
km

Temporal variability

- **Generally, between 1961-2020, annual average flows have a downward trend. The highest decreasing trend is registered in the east of the country and in southern part of Romania.**
- **There are very large discrepancies between dry and very rainy years.**

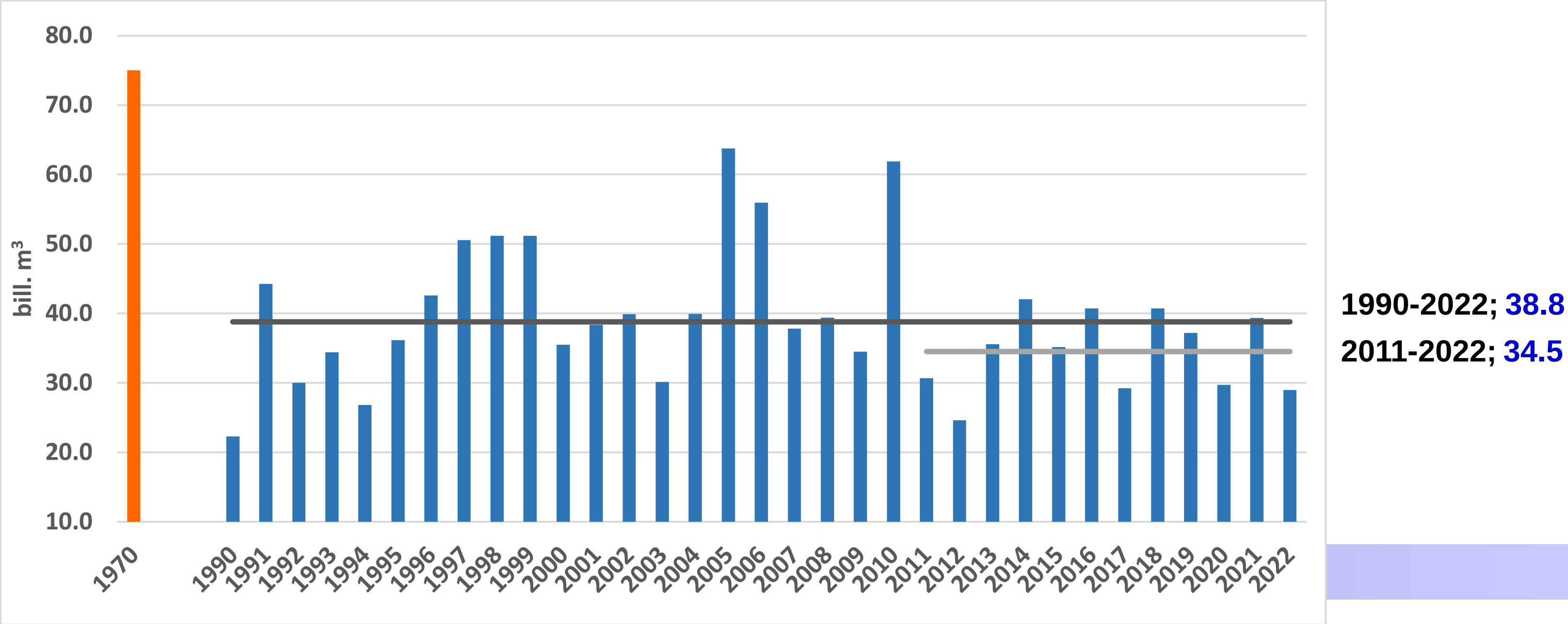






Temporal variability

- The current multi-annual flow (2011-2022) is generally lower than in the previous period (2001-2010) when Romania faced extreme phenomena such as historic floods on the inland rivers (2005, 2008 and 2010), historical floods on the Romanian Danube River sector in 2006, as well as the extreme drought in the last 60 years, registered in 2007.
- The trend of decreasing annual average flows can be attributed to climate change. Over the last 50 years, Romania has experienced a rise in temperature, accompanied by a drop in precipitation.



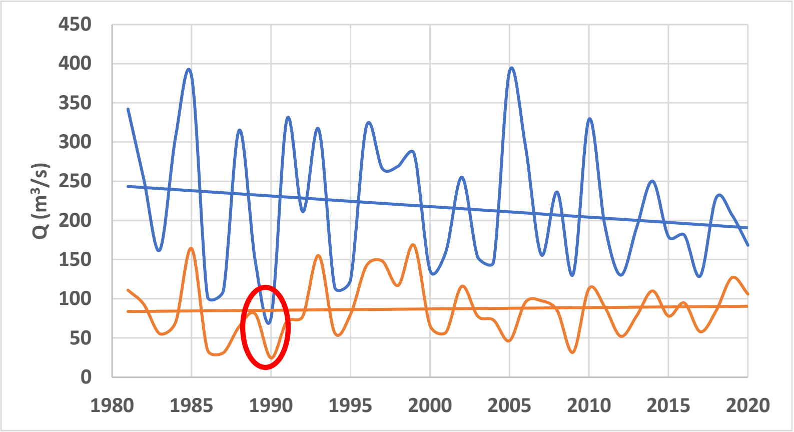
The situation of dry years (droughts) is of particular interest in the drastic decrease of available resources;

In the driest year (1990), the annual runoff volume was 50% below of the multiannual average for 9 of the 15 large hydrographic basins

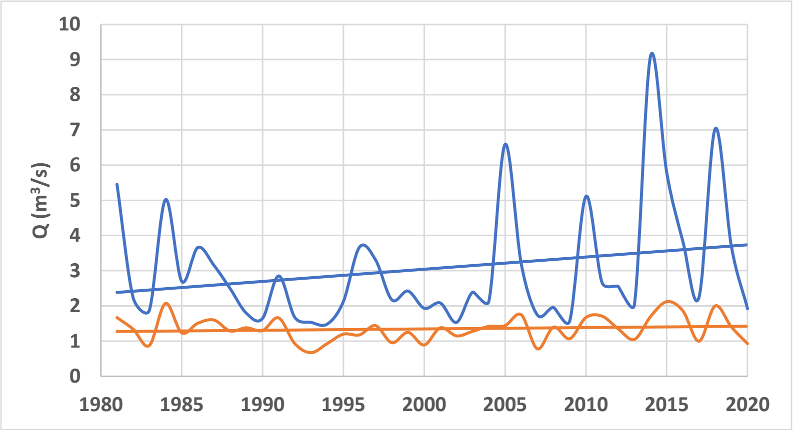
For the entire national hydrographic network the weight of the total water resources was 54% of the multiannual average;

In a very dry year, the volume of the natural water resources is almost halved.

Siret



Teleorman



Minimum runoff indices

- BFI - The ratio of annual baseflow in a river to the total annual runoff on a river
- Q_{med} - multiannual average flow
- Q95, Q90 - 95 and 90 percentiles of the daily average flow duration curve
- Flow deficit - hydrological drought event characterized by duration, volume, intensity, minimum flow and duration time

✓ series of daily average flows from 132 hydrometer stations located on Romanian rivers

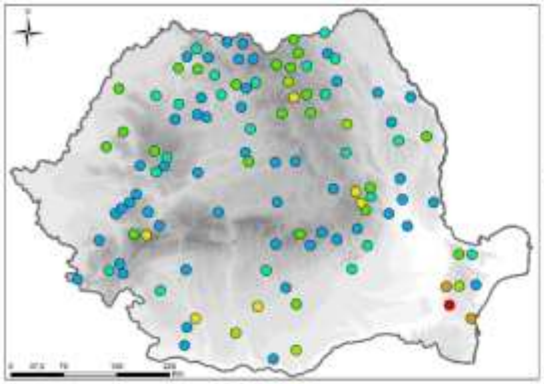
✓ Analysis period: 1970-2015

Hydrological Drought – Current Trends

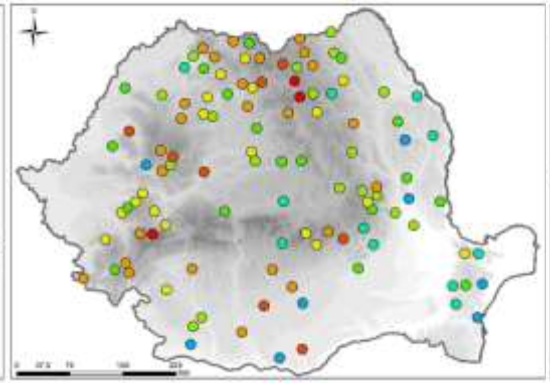
Minimum runoff indices

Maximum annual streamflow deficits (below Q90 threshold)

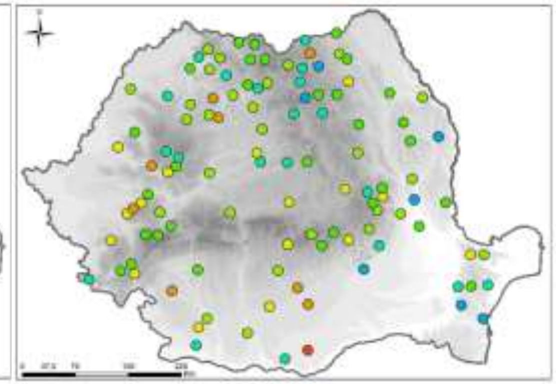
1971 – 1980



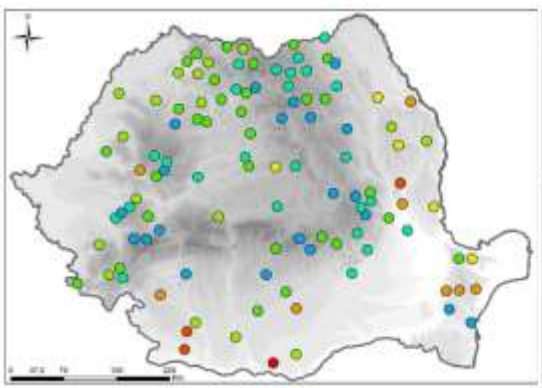
1981 – 1990



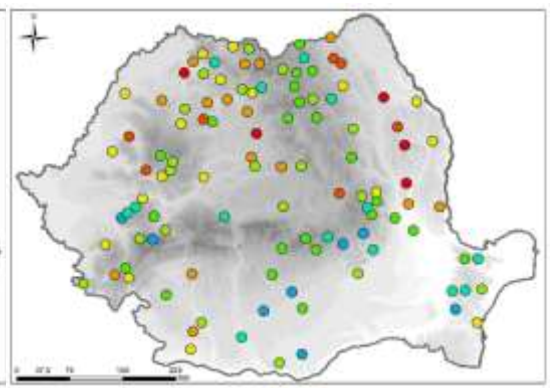
1991 – 2000



2001 – 2010



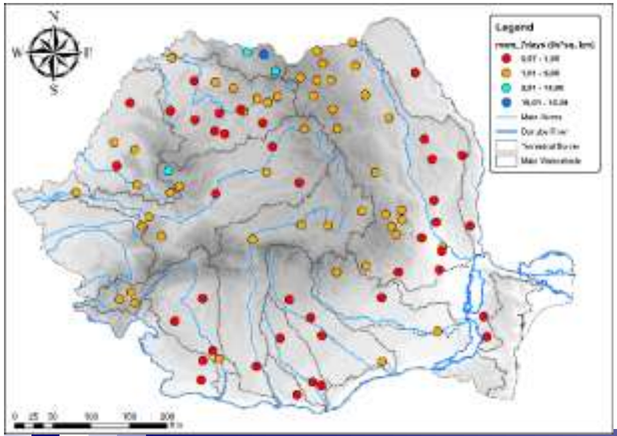
2011 - 2017

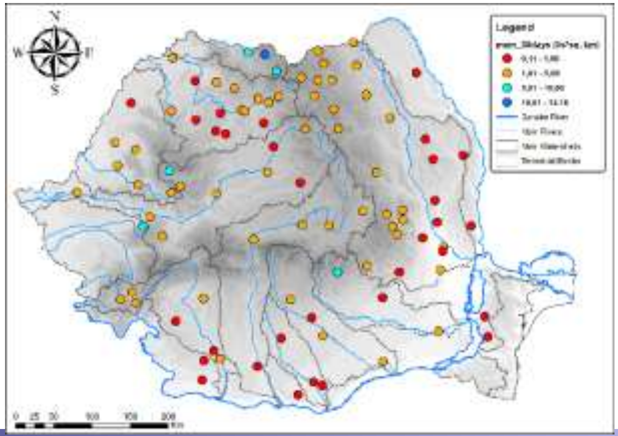


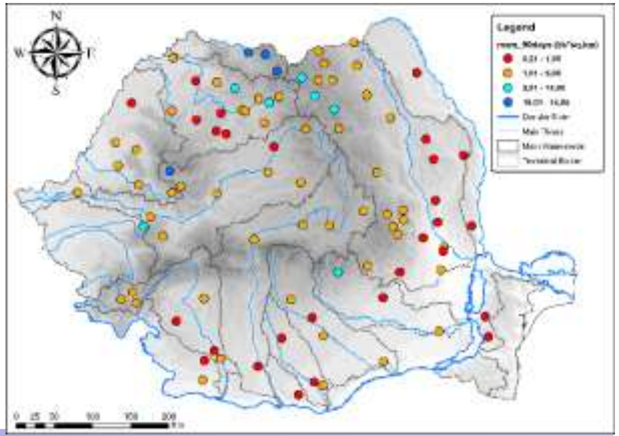
no. of events with deficits per decade (with durations more than 30 days) 0 1 2 3 4 5 6 7

Minimum runoff indices –
Low flow indices on the Romanian rivers (1980 – 2020, at 93 station)

- the low flow analysis were made based on the specific values of mean annual minima over different time durations, such as mam7, mam30, and mam90;
- this analyze emphasize the variability of specific low flow for time durations from 7 to 90 days, with values in the ranges: 0.07 – 10.4 l/s*km^2, 0.11 – 12.2 l/s*km^2, respectively 0.21 – 14.9 l/s*km^2;
- the percentage of values under 1 l/s*km2 (red symbol) is declining from 43% (in case of mam7) to 30.1% (in case of mam90), which proves a low variability of minimum discharges from one to three months period.

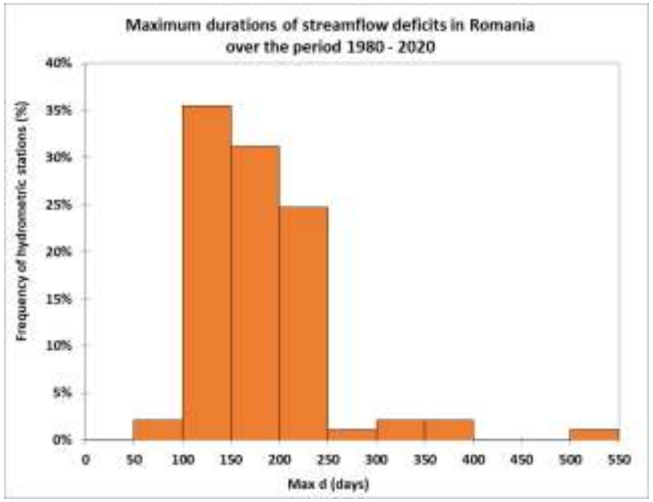




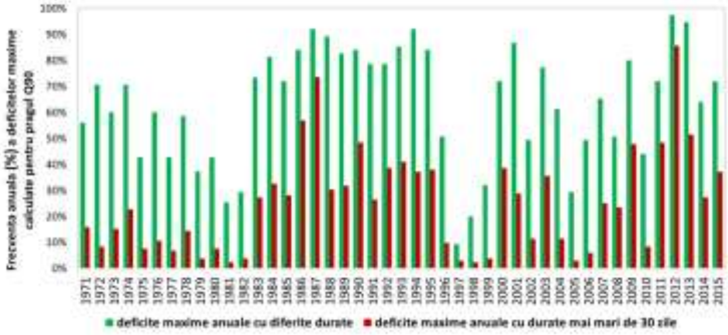


Minimum runoff indices –
Annual maximum streamflow deficits below Q80 threshold level (the 20th percentile of flow duration curve) and duration more than 30 days

- **the histogram of durations corresponding to the maximum annual deficits shows the deficits with durations ranged from: 100 to 150 days for 35% of stations, 150 to 200 days for 33% stations, and 200 to 250 days for 24% of stations, respectively.**

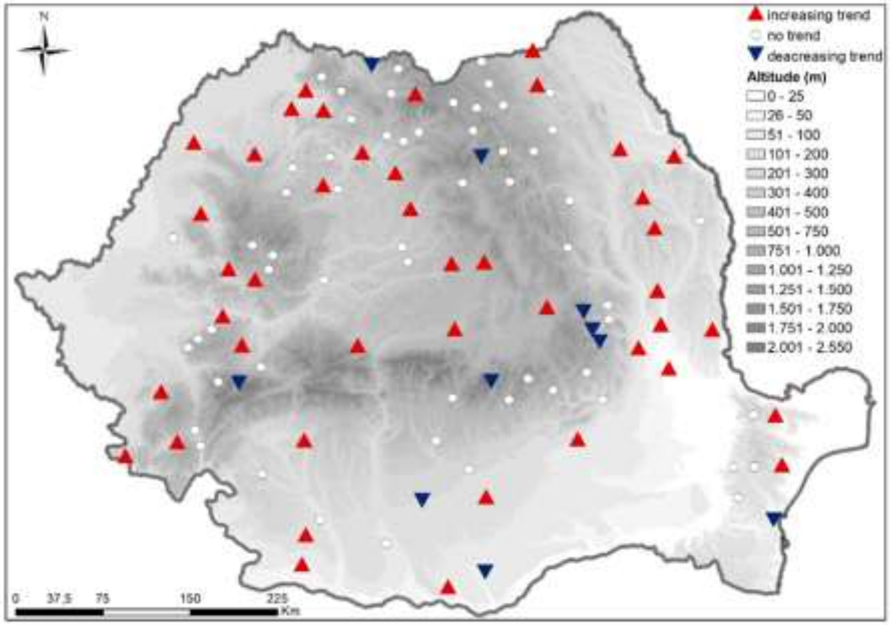


- **it was found that for 56% of the total number of hydrometric stations (on inland rivers), the largest deficits occurred during the last two decades, in the following years: 2000 - 2003, 2011 - 2013, 2015, 2017, 2019 and 2020;**
- **The analysis of the runoff deficit frequency reveals the period of the last 10 years as the most affected by the hydrological drought.**



Minimum runoff indices –
Low flow indices on the Romanian rivers (1980 – 2020, at 93 station)

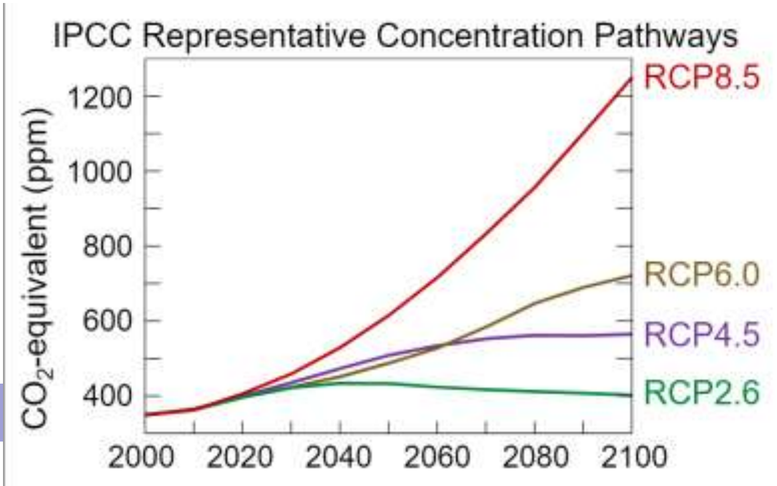
- **The trend analysis for the period 1971 – 2019 highlighted the presence and persistence of a minimum and average runoff deficit regime for approximately 30% of the studied river basins.**
- **50% of all analyzed RGS showed significant decreases in minimum flow indicators for a confidence level higher than 90%.**
- **Increasing trends both for deficit (volume) and for duration, for the Q90 and Q95 thresholds, were detected at 39 RGS (35.5% of the total analyzed stations) and, respectively, at 33 RGS (30% of all stations analyzed).**



Streamflow deficits and durations

Climate change and water

- For Central and Southern Europe, an increase of 1°C above the global average is forecast in both the +2°C and +1.5°C scenarios.
- According to the latest reports, the climatic extremes of recent years had a negative impact on the entire continent.
- At European level, vulnerability is expected to increase as a result of climate change, but climate projections still have a high degree of uncertainty.
- The differences between the results of the different scenarios are particularly significant for the period 2061-2090.

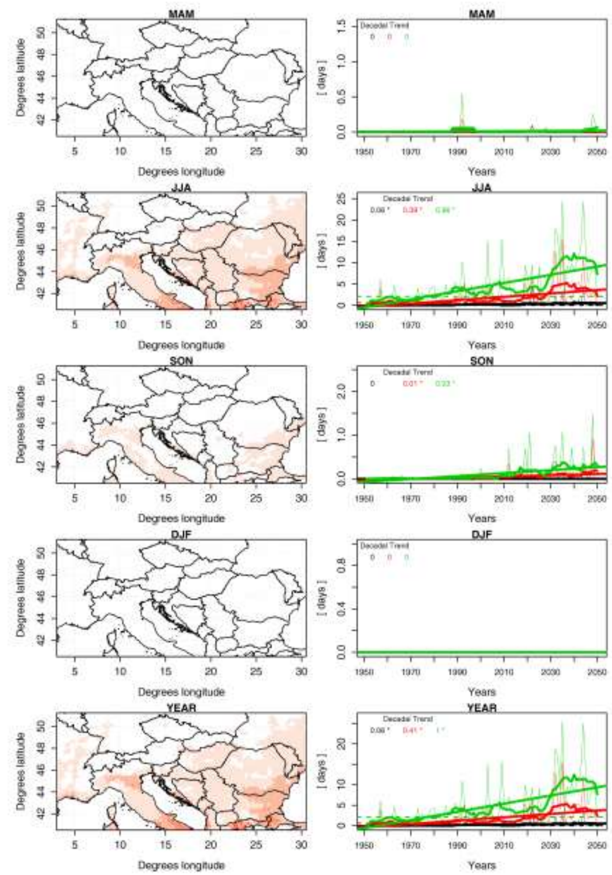


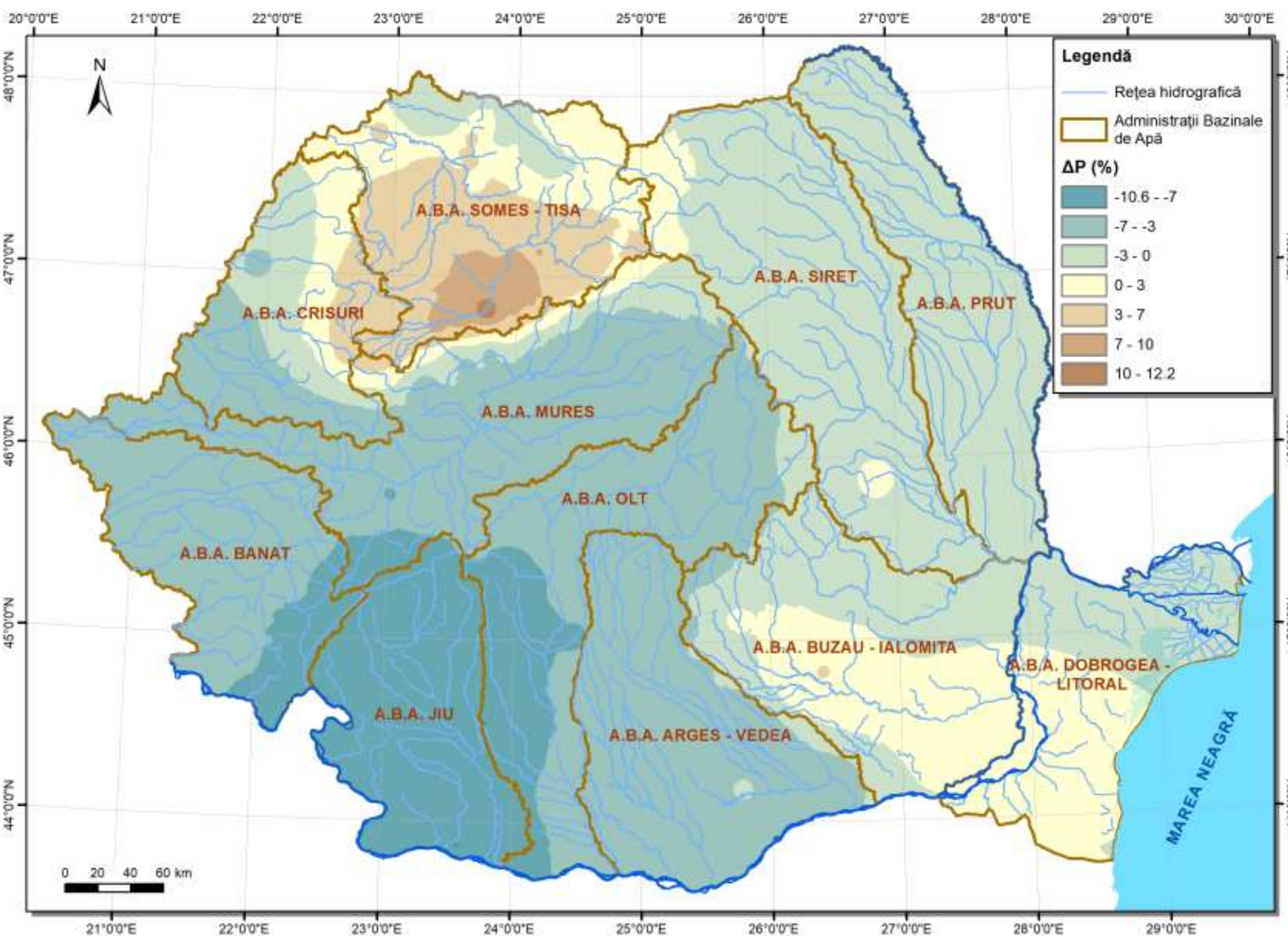
Potential climate change impact on mean flow in Romania

In order to estimate the impact of climate changes on the monthly, seasonal and annual discharge, long-term simulations were carried out using the WATBAL and CONSUL hydrological models.

As input data, precipitation and temperature series resulting from the processing of regional climatic projections produced within CLAVIER Project, based on REMO 5.7 model for A1B scenario, corrected using STAT-CLIMATE-ECA database and refined temporally (6 hours) and spatially (~10 km) were used.

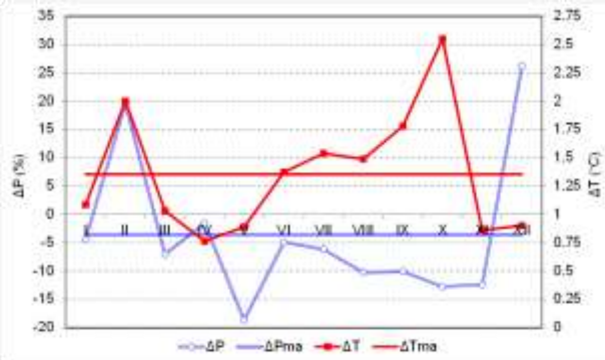
The hydrological simulations were carried out for the reference and the future periods, respectively: 1971-2000 (Scenario 0) and 2021-2050 (Scenario 1).

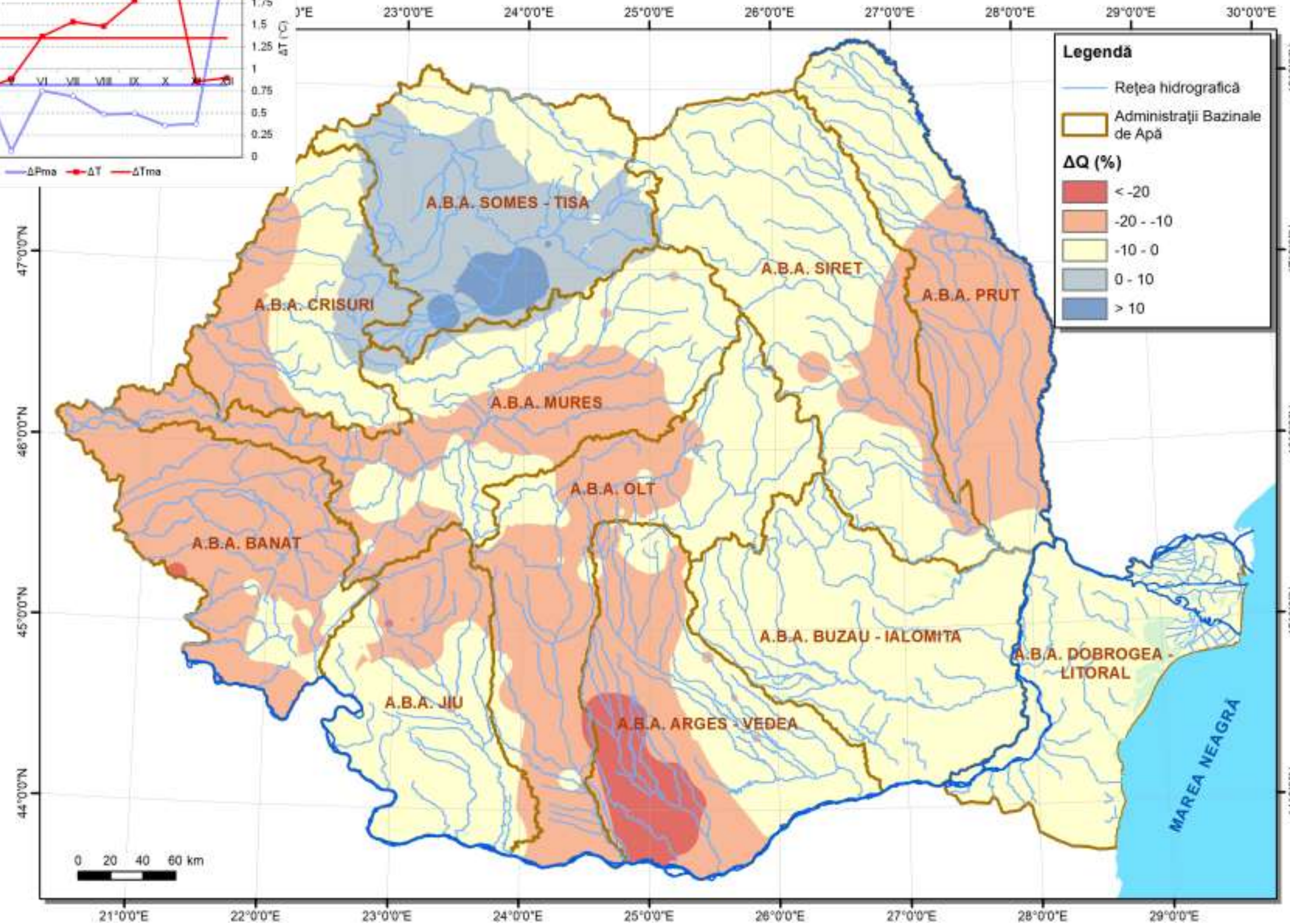



Legendă
Rețea hidrografică
Administrații Bazinale de Apă
ΔP (%)
-10.6 - -7
-7 - -3
-3 - 0
0 - 3
3 - 7
7 - 10
10 - 12.2
A.B.A. SOMES - TISA
A.B.A. CRISURI
A.B.A. SIRET
A.B.A. PRUT
A.B.A. MURES
A.B.A. OLT
A.B.A. BANAT
A.B.A. BUZAU - IALOMITA
A.B.A. DOBROGEA - LITORAL
A.B.A. JIU
A.B.A. ARGES - VEDEA
MAREA NEAGRĂ
N
0 20 40 60 km

Results analysis of the variation of the mean multiannual discharges from S1 Scenario vs. S0 Scenario in the river basins from Romania - example

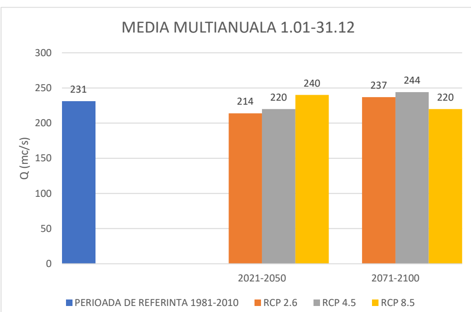
River basin	*Monthly mean multiannual discharges variation*	*Seasonal mean multiannual discharges variation*	*Mean multiannual discharges variation*
Someș	**● Significant increase in December, January, February and March, and decrease in May and October.**	**● Growth in winter, spring and summer and decrease in autumn.**	**● Increase, of maximum 23.4 %**
Mureș	**● Significant increase in January, February and March, and decrease in August, September, October and November.**	**● Growth in winter and decrease in other seasons.**	**● Decrease, of maximum -14.2 %**
Moravița	**● Decrease of discharges in all months of the year, more pronounced in March, April and September – December.**	**● Decrease in all the seasons**	**● Decrease, of maximum -24.6 %**
Caraş	**● Slight increase in February and decrease in the other months, with more pronounced decreases in March and September to November.**	**● Lighter decreasing, in summer and winter and more pronounced in other seasons**	**● Decrease, of maximum -18.8 %**
Olt	**● Significant increase in January and February and decrease in April, May, June, October and November**	**● Growth in winter and decrease in other seasons.**	**● Decrease, of maximum -14.4 %**
Vedea	**● Increase in February and decrease in all other months, more pronounced in the period March – July.**	**● Slight increase in winter and decrease in other seasons.**	**● Decrease, of maximum -38.4 %**
Argeș	**● Significant increase in February, March and December, and decrease in May, September and October.**	**● Growth in winter and decrease in other seasons.**	**● Decrease, of maximum -12.2 %**
Siret	**● A significant increase in February and March and decrease in April, May, August, September and November.**	**● Growth in winter and decrease in other seasons.**	**● Decrease, of maximum -13.4 %**

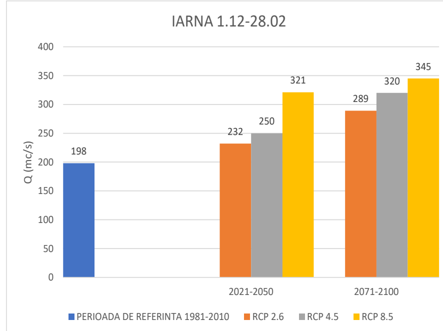

ΔP (%)
ΔT (°C)
I II III IV V VI VII VIII IX X XI XII
ΔP
ΔPma
ΔT
ΔTma

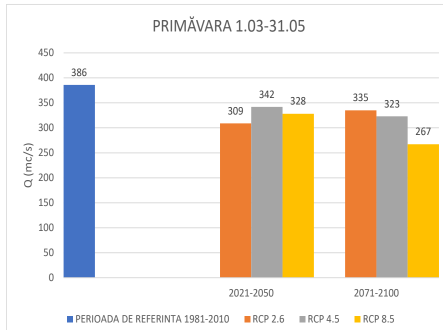

Legendă
Rețea hidrografică
Administrații Bazinale de Apă
ΔQ (%)
< -20
-20 - -10
-10 - 0
0 - 10
> 10
A.B.A. SOMES - TISA
A.B.A. CRISURI
A.B.A. SIRET
A.B.A. PRUT
A.B.A. MURES
A.B.A. OLT
A.B.A. BANAT
A.B.A. JIU
A.B.A. ARGES - VEDEA
A.B.A. BUZAU - IALOMITA
A.B.A. DOBROGEA - LITORAL
MAREA NEAGRĂ
0 20 40 60 km

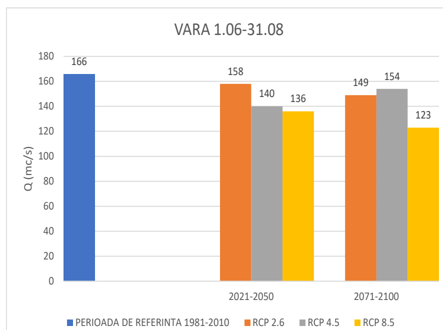
Potential climate change impact on mean flow in Romania - results

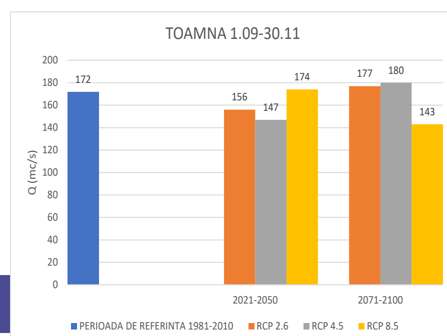
- Regarding the seasonal mean multiannual discharges, generally an increase of discharge in winter and a decrease of theirs in the other seasons was obtained.
- At the level of multiannual mean discharges, the simulations generally indicated for the analyzed river basins a decrease trend of maximum -15 % (lower values being obtained for the hydrographic basins in the northwest of the country, maximum -5 %, and higher, up to -40 % in the Vedea River basin), except for the Someş River Basin for which a increase of maximum 25% was obtained.



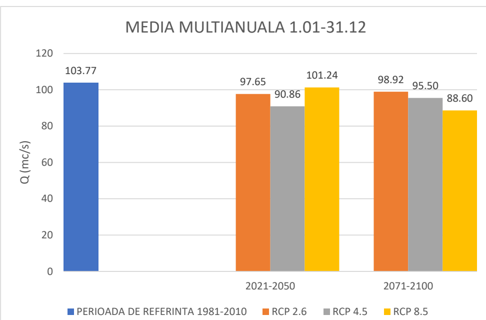


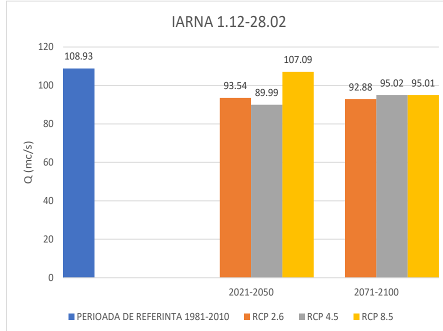


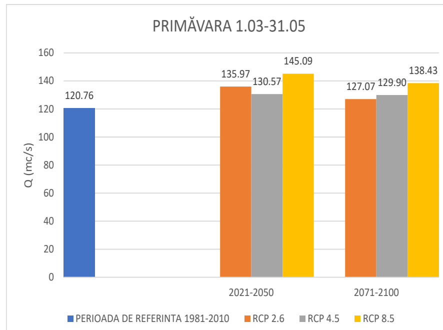


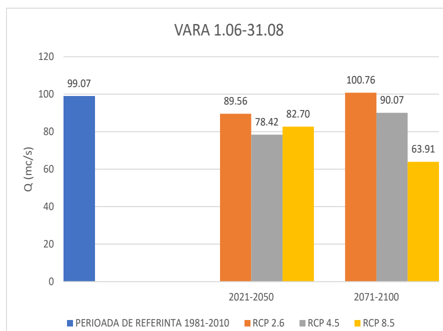


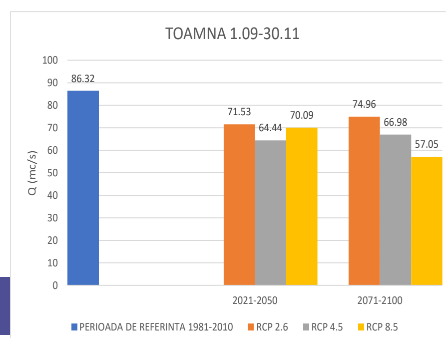
Nr. crt.	Bazinul hidrografic	F (km²)	Qmed multianual 1981-2010 (mc/s)	Qmed multianual 2021-2050 (mc/s)	Raport 2021-2050 fata de 1981-2010	Qmed multianual 2071-2100 (mc/s)	Raport 2071-2100 fata de 1981-2010
1	Viseu (Tisa)	283	12.1	11.8	-2.5%	12.5	3.3%
2		411	10.7	10.5	-1.9%	11.0	2.8%
3		435	18.8	18.3	-2.7%	18.7	-0.5%
4		**1545**	**37.1**	36.9	-0.5%	39.0	5.1%
5	Iza (Tisa)	68.2	1.42	1.39	-2.1%	1.50	5.6%
6		102	4.04	3.78	-6.4%	4.15	2.7%
7		390	13.7	12.9	-5.8%	13.9	1.5%
8		**1109**	**31.0**	29.1	-6.1%	32.1	3.5%
9	Tur (Tisa)	37	2.34	2.25	-3.8%	2.36	0.9%
10		164	6.40	6.17	-3.6%	6.41	0.2%
11		**731**	**20.1**	19.2	-4.5%	20.5	2.0%
12	Someșul Mare	292	8.47	8.00	-5.5%	8.50	0.4%
13		99.7	6.29	5.92	-5.9%	6.36	1.1%
14		230	4.08	4.02	-1.5%	4.28	4.9%
15		598	25.4	25.1	-1.2%	26.5	4.3%
16		1795	30.5	29.8	-2.3%	32.4	6.2%
17		354	7.39	7.22	-2.3%	7.98	8.0%
18		98.5	2.37	2.35	-0.8%	2.57	8.4%
19		404	16.7	16.2	-3.0%	17.4	4.2%
20		**4344**	**83.5**	82.0	-1.8%	88.1	5.5%
21	Lăpuș	222	12.1	11.7	-3.3%	12.5	3.3%
22		246	8.48	8.23	-2.9%	8.76	3.3%
23		261	11.1	10.8	-2.7%	11.4	2.7%
24		**1468**	**39.0**	37.6	-3.6%	40.9	4.9%
25	Someșul unit aval Dej	455	6.03	5.57	-7.6%	6.32	4.8%
26		223	2.22	1.99	-10.4%	2.39	7.7%
27		555	3.02	2.75	-8.9%	3.34	10.6%
28		8842	127	123	-3.1%	138	8.7%
29		**15380**	**231**	220	-4.8%	244	5.6%
30	Someșul Mic	1202	18.3	17.1	-6.6%	19.8	8.2%
31		1854	29.6	28.7	-3.0%	30.2	2.0%
32		282	1.47	1.37	-6.8%	1.67	13.6%
33		174	1.42	1.28	-9.9%	1.51	6.3%
34		**3590**	**27.0**	25.8	-4.4%	29.7	10.0%
35	Crasna	210	2.74	2.60	-5.1%	2.88	5.1%
36		937	8.25	7.82	-5.2%	8.84	7.2%
37		168	1.42	1.32	-7.0%	1.54	8.5%









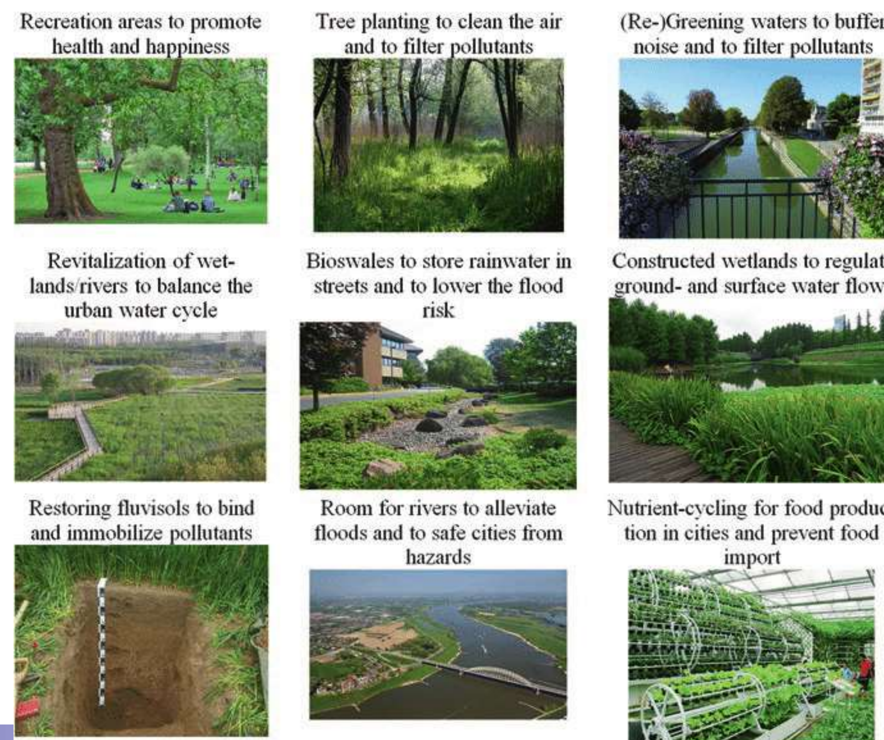


Nr. crt.	Bazinul hidrografic	F (km^2)	Qmed multianual 1981-2010 (mc/s)	Qmed multianual 2021-2050 (mc/s)	Raport 2021-2050 fata de 1981-2010	Qmed multianual 2071-2100 (mc/s)	Raport 2071-2100 fata de 1981-2010
1	Vedea	228.0	1.03	0.92	-10.48%	0.92	-10.97%
2		396.4	2.41	2.15	-10.75%	2.18	-9.30%
3		442.5	3.94	3.45	-12.54%	3.70	-6.27%
4		497.0	4.23	3.73	-11.94%	4.06	-4.13%
5		1322.5	7.09	6.44	-9.22%	6.54	-7.74%
6		1734.6	12.43	10.90	-12.30%	11.55	-7.10%
7		**3265.3**	**20.27**	**17.86**	**-11.85%**	**18.62**	**-8.10%**
8	Argeș	147.4	1.79	1.62	-9.35%	1.68	-6.22%
9		263.3	9.02	8.24	-8.67%	8.74	-3.10%
10		3793.5	76.92	69.71	-9.38%	73.43	-4.54%
11		**9309.8**	**103.77**	**90.86**	**-12.44%**	**95.50**	**-7.97%**
12	Dâmbovița	50.6	1.69	1.57	-6.96%	1.63	-3.70%
13		258.7	7.96	7.41	-7.02%	7.79	-2.24%
14		644.5	19.29	18.04	-6.48%	18.94	-1.78%
15		1084.2	21.01	19.31	-8.07%	20.15	-4.09%
16		**2783.3**	**41.20**	**38.61**	**-6.28%**	**39.80**	**-3.40%**
17	Neajlov	384.8	2.07	1.78	-14.15%	1.83	-11.93%
18		657.3	3.44	2.86	-16.71%	3.04	-11.65%
19		1295.6	7.07	6.00	-15.09%	6.20	-12.31%
20		**3443.7**	**20.44**	**17.30**	**-15.36%**	**18.05**	**-11.70%**
21	Râul Doamnei	57.7	2.27	2.11	-7.07%	2.15	-5.31%
22		360.7	21.59	20.60	-4.58%	21.63	0.19%
23		846.4	14.92	13.42	-10.05%	13.94	-6.57%
24		**1739.3**	**36.06**	**32.70**	**-9.32%**	**34.16**	**-5.27%**
25	Sabar	1174.2	**7.28**	**6.15**	**-15.55%**	**6.40**	**-12.12%**

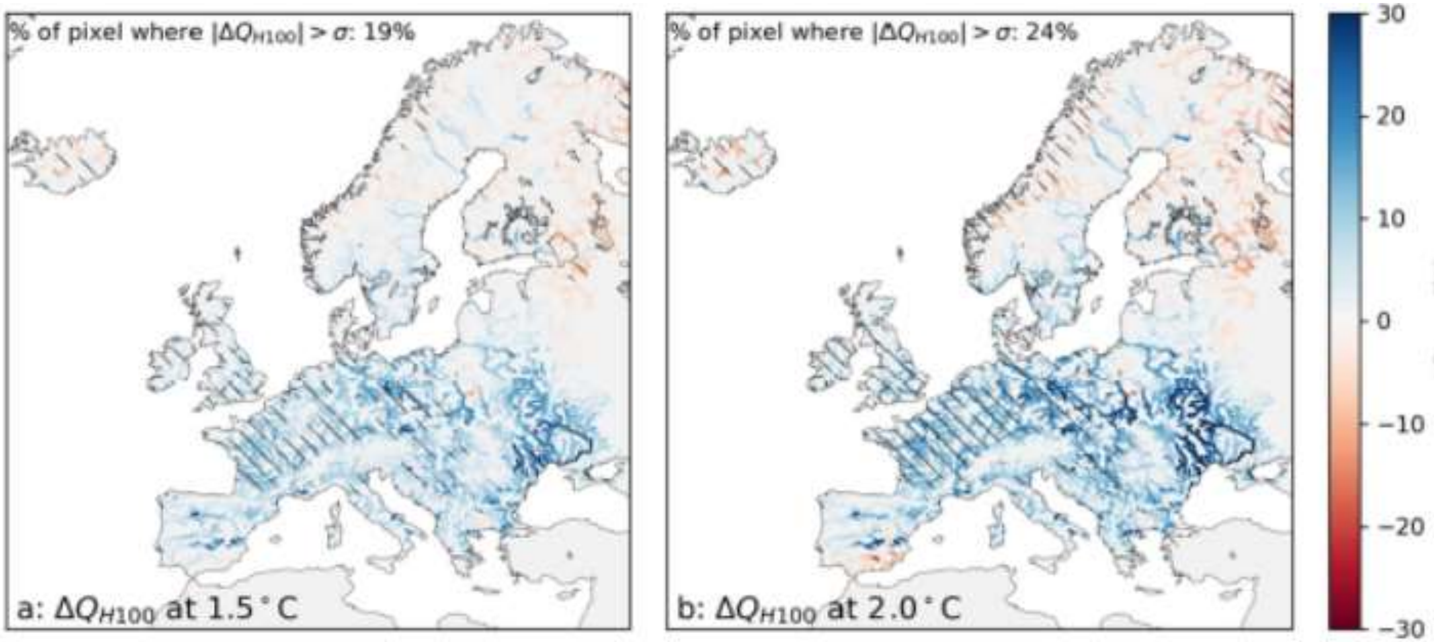
Measures and actions to reduce the impact

- **The EU Climate Change Adaptation Strategy highlights a number of actions related to flood risk management and mitigation, with a particular focus on removal knowledge gaps on climate impacts, resilience, as well as nature-based solutions.**

- **In some countries, the impact of climate change is already taken into account in the design phase of new structural measures, or at least measures with multiple benefits are taken into account.**



- **Main adaptation actions at national level:**
  - **Development of updated climate scenarios for our country**
  - **Supporting research activities in the field of climate change**
  - **Climate change cost estimation for each priority sector**



Estimation of the relative changes in maximum flows with a exceeding probability of 1%, assuming an increase in the average temperature by 1.5^{0}C (a), respectively 2^{0}C (b), for river basins with an area > 500 km^2

Conclusions

- The signal of climate change is different from one model to another. But overall, the models estimation is consistent with current trends.
- Generally, an increase of discharge in winter and a decrease of theirs in the other seasons was obtained.
- At the level of water resources, was highlighted a decrease trend of maximum -15% at the RB level (lower values in the northwest of the country, maximum -5 %, and higher, up to -40 % in the Vedea River basin).
- 50% of all analyzed RGS showed significant decreases in minimum flow indicators.
- Increasing trends both for deficit (volume) and duration, for the Q90 and Q95 thresholds, were detected at 30-35% of the total analyzed stations.
- Protection and adaptation measures must be complementary.
- The impact of climate change must be carefully taken into account in the design phase due to increasing costs.