REPORT ON GENDER-SENSITIVE CLIMATE RISK ASSESSMENTS FOCUSSING ON FILLING THE INFORMATION GAPS AND PRIORITY ACTIONS THAT ADDRESS CLIMATE-DRIVEN VULNERABILITIES AND GENDER-DISAGGREGATED IMPACTS OF THE WATER SECTOR

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CAOS sustentabilidade

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Objective of this document

The objective of this report is to identify the existing and future climate change risks, vulnerabilities and impacts for the Montenegrin water sector. The results will form part of Montenegrin climate change response strategies and support the implementation of the country's wider National Adaptation Plan (NAP). Prior to the development of this report, an analysis of the policy framework has been undertaken in order to identify opportunities for mainstreaming climate change into water related policies and planning processes.

Understanding the vulnerability of water resources is vital to ensuring sustainable water management in the country. Undertaking the vulnerability assessment of water resources identifies the most dominant factors that influence vulnerability. The availability of such an assessment provides the decision-makers with various alternatives to evaluate and modify existing policies/strategies and implement measures to improve water resources management.

Executive summary

The territory of Montenegro is divided into two basins: Adriatic Sea Basin and Danube River Basin. The main rivers within the Adriatic Sea Basin are: Moraca, Zeta, Cijevna and Bojana, and within the Danube River Basin: Piva, Tara, Lim, Ibar and Cehotina.

With average total renewable freshwater resources of 19.5 km³/year, Montenegro ranks among the top 4% of world countries by average outflow. Given that at least 95.3% of Montenegro's flow originates in its territory, it is safe to say that water is the country's greatest natural resource, having in mind that in many parts of the region of SEE the water resources are scarce, particularly in summer months. The average availability per inhabitant in Montenegro is 31,339 m³/year. The huge quantities and the quality of the surface water bodies results in significant water potential, which can be transformed into hydropower potential.

On the other hand, the water delivered to the final consumers is constantly decreasing. According to the Energy and Water Regulatory Agency of Montenegro (REGAGEN), the non-revenue water on national level in 2020 is 67.14%, which states that the management of the water resources is not on appropriate level and the water losses in the water distribution system are huge.

The largest floods in Montenegro since the half of the past century until now have occurred in: 1963, 1979, 1999, 2000, 2010 and 2011. Although Montenegro can be exposed to all kinds of floods, two categories of floods are characteristic: (1) Fluvial floods which are result of abundant rain series of a few days with a large amount of rainfall, which in extreme cases can reach about 500~1000 lit/m2, covering larger space and (2) Meteorological floods (pluvial and flash floods) which are local; they are more likely to occur and they are related to torrents and urban environments or a certain fragment of space.[1]

The assessment of the historic climatic data shows an increase in temperature over the last three decades of approximately 1°C, with a greater increase occurring in minimum average temperatures. The increase is more emphasized in the last three decades.The lowest annual amounts of precipitation is observed in the period from 1980 to 2000, a period which according to the SPEI index is also characterized as a dry period.The number of days with more than 1 mm precipitation has significantly decreased, and the number of days with more than 40 mm has increased, however, indicating that climate has become drier and with more frequent extreme precipitations.

The climate projections of Montenegro show an increase in the annual temperature of 1.5° C to 2° C by 2040 throughout the country, while for the period 2041–2070 the deviations of the mean annual temperature range from 2.5° C to 3° C.

The assessment of climate adaptation in the relevant sectoral and climate protection legislation has concluded that there is no legally established framework for climate adaptation planning in the country, despite the existence of various Laws and planning processes that somehow relate to climate change adaptation. Taking into consideration all conclusions listed above, one of priorities of the NAP Project should be to define, legally regulate and institutionalize the national climate adaptation planning processes.

The potential impacts of climate change on the WSS sector are presented in Figure bellow:

[1] https://flat-project.org/profile-montenegro

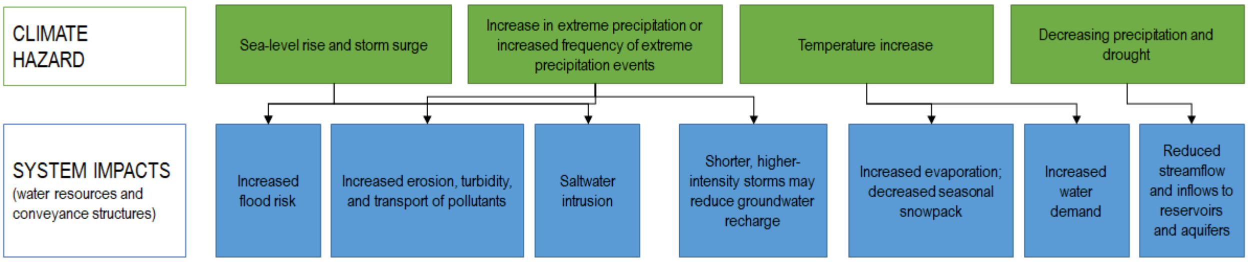


Figure 1 Potential impacts of climate change on the WSS sector

In order to assess the vulnerability of the water sector to the various climatic variables, the following analyzes were carried out as part of this assessment:

- Water balance/budget assessment, represents quantification of Montenegro's waters, which is sought to be carried out by analysis and comparison of water availability against water use/demand data, including climate change effects.
- Water Footprint (WF). As another concept that is used to establish a better understanding of the critical role of water resources for country's water security and resilience to climate change.
- Vulnerability assessment of floods through the integration of spatial and economic modelling, and
- Susceptibility assessment of torrential floods
- Economic vulnerability assessment of fluvial floods

The conclusions from the assessment of the climate vulnerability and the economic and gender disaggregated impact of the water sector are summarized as it follows:

- Possible climate changes that are expected in the future, resulting in decrease of precipitation and increasing of actual evapotranspiration (and modification of their time distribution), may cause decreasing of average annual flow of 30% by the end of the 21st century. In the summer period, these changes are even more drastic and result in a water deficit in some of the sub-basins.
- Not counting water for hydropower production, WEI[2] for Montenegro is about 1% (as one of the Indicators of SDG 6 - Ensure availability and sustainable management of water and sanitation for all). Major changes of this indicator on annual basis are not expected in the future period either.
- WEIs for summer months present the worst-case scenarios regarding water stress, which are very important in water resources management, since in summer season water demand is much higher and droughts are more frequent in the last decades. Analyzes show that a significant number of watersheds in the future may face water stress in the summer months under the influence of climate change and increased water consumption.
- A significant reduction of water surplus can be observed in some of the basins compared with the baseline scenario. A water surplus simulation was also made with an increase in water consumption (water demand) at the level of the entire country by 50% by the end of the

[2] The water exploitation index (WEI) in a country is the mean annual total demand for freshwater divided by the long-term average freshwater resources. It gives an indication of how the total water demand puts pressure on the water resource.

century. In such a scenario, the reduction of excess water in some of the basins is drastic and reaches up to 70%.

- The amount of available renewable water sources per inhabitant in Montenegro is 31,700 m3/capita/year. Under the influence of possible climate changes, these quantities are expected to be reduced to 22,500 m3/capita/year without future population growth.
- The north and north-eastern part of Montenegro is the most susceptible to torrential flooding, along with the coastal region.
- According to the WWT [3]methodology Montenegro is a clear net importer of water, as hinted even in Table 7, where trade is represented monetarily, especially through industrial products. The total net import of goods is 1.75 billion euro.
- The total economic damage of reduced electricity production in hydropower plants due to the effects of climate change by 2100, in the case of higher electricity import prices in the future, could exceed EUR 5 billion, which for a small country like Montenegro certainly represents a significant amount.
- The expected annual national damages (EAD) from synthetic flood episodes with different return period are estimated on 142 million euros.

Having in mind the identified vulnerabilities and the projected socio-economic impacts of the climate change on the water resources of Montenegro, it is very clear that Montenegro should develop comprehensive, cross-compliant and gender sensitive climate mitigation and adaptation policy for the water sector, as well as to invest in the conservation and protection of the water resources and water infrastructure in the country.

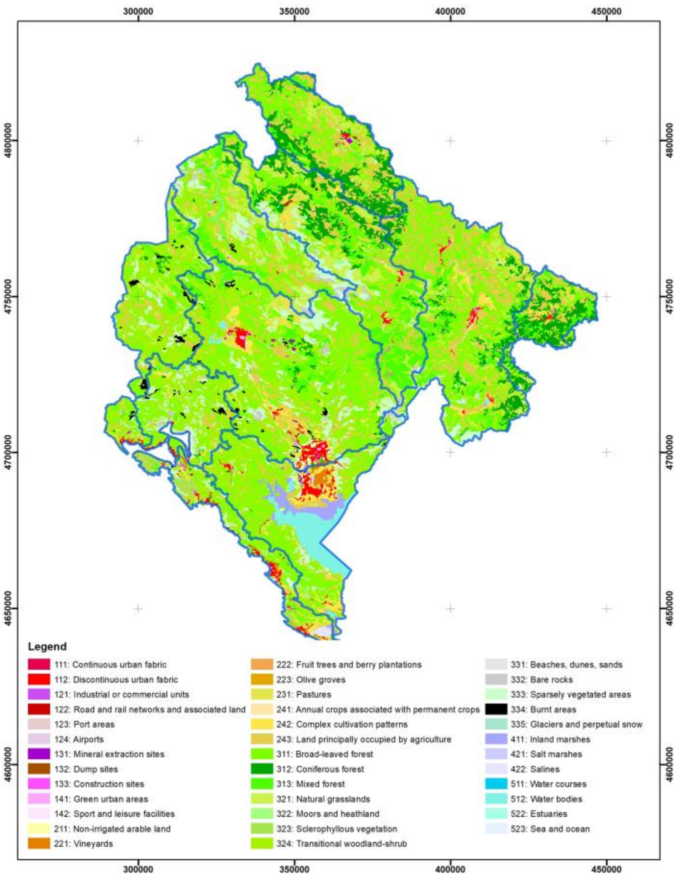
[3] The virtual water trade (also known as embedded or embodied water) is **the hidden flow of water in food or other commodities that are traded from one place to another**. The virtual water trade is the idea that when goods and services are exchanged, so is virtual water.

1. Overview of the national circumstances relating to Water sector of Montenegro

1.1. Geographic profile relevant for the sector and overview of the sectoral infrastructure

Montenegro is located in the central part of a moderately warm zone in the Northern Hemisphere (41°52’ and43°32’ latitude North and 18°26’ and 19°22’ longitude East). Owing to its latitude, i.e. its proximity to the Adriatic and Mediterranean Seas, it has a Mediterranean climate with warm and somewhat dry summers and mild and rather humid winters. The dominant climate types in Montenegro are: Maritime, Continental and Mountainous.

According to data from the Corine Land Cover (CLC) database, 79.23% of the total territory of Montenegro is covered by forests and semi natural areas, 16.09% is agricultural land, 1.9% water bodies and 1.87% is artificial areas.



Sum of Area CLC ha	Column Lab												
Row Labels	Boka Bay	Cehotina	Drina	Ibar	Lake Skadar/Shkoder	Lim, Drina	Morača and Zeta	Piva, Drina	Tara	Trebišnjica, Gatačko Polje	Ulcinj - Budva	White Drin River	Grand Total
Arable land	31				153	90	488						762
Artificial, non-agricultural vegetated areas	25				11		555		191		640		1,422
Forests	21,483	57,522	1,872	24,739	44,476	119,801	115,008	35,968	90,133	38,491	17,023	4,098	570,616
Heterogeneous agricultural areas	4,402	24,689	1,304	7,926	21,023	51,818	30,487	11,252	20,989	10,061	8,124	59	192,135
Industrial, commercial and transport units	48	83		63	787	289	589	52			545		2,457
Inland waters	26	128			23,377	234	1,363	1,552	78	442			27,198
Inland wetlands					10,273	128	139				289		10,829
Marine waters	4				37					4	81		126
Maritime wetlands											1,534		1,534
Mine, dump and construction sites	61	661		36	316		958		434	55	359		2,881
Open spaces with little or no vegetation	14,835	468		133	11,963	8,582	32,034	20,544	14,687	12,621	4,522	558	120,948
Pastures	366	1,212	21	1,390	1,578	3,812	10,595	2,476	3,785	699	669		26,603
Permanent crops					2,433	74	473				515		3,496
Scrub and/or herbaceous vegetation associations	32,106	22,597	171	6,868	36,365	45,790	83,024	49,404	52,199	53,451	20,771	3,414	406,161
Urban fabric	1,455	297		291	3,927	1,566	6,268	99	996	712	3,788		19,400
Grand Total	**74,842**	**107,658**	**3,367**	**41,448**	**156,720**	**232,183**	**281,982**	**121,348**	**183,492**	**116,535**	**58,862**	**8,129**	**1,386,566**

Figure 2 CLC 2018 for Montenegro with division by river basins

The average annual air temperature ranges from 5.3°C in the area of Žabljak which is 1,450 m above sea level to 16.1°C on the coast. The average annual precipitation ranges from 790 mm in the far north (Plevlja) to around 3,350 mm in the far southwest (Cetinje).

During the year, there are between 115 and 130 days of rainfall on average and 172 days of rainfall in the northern regions of Montenegro[4]. The rainiest month on the coast is November, and the driest is July. Snow cover forms at altitudes above 400 MSL, and with a depth of more than 50 cm it lasts on average from 10 days (in Kolašin) to 76 days (in Žabljak).

The seasonal air temperature data for Montenegro (produced by the Climatic Research Unit of University of East England. presented at a 0.5º x 0.5º resolution) are presented in the Table below..

[4] BUR/BUR3/2022 – UNFCCC https://www4.unfccc.int/sites/SubmissionsStaging/NationalReports/Documents/68702541_Montenegro-BUR3-1-BUR3_Montenegro%20-%2024.%20Jan%20-%20FINAL.docx

Table 1 Seasonal average, min-average and max-average temperatures

	1991-2020				1961-1990				1960-1931				1930-1901			
Temperature average values (mean)	**December-January-February**	**March-April-May**	**June-July-August**	**September-October-November**	**December-January-February**	**March-April-May**	**June-July-August**	**September-October-November**	**December-January-February**	**March-April-May**	**June-July-August**	**September-October-November**	**December-January-February**	**March-April-May**	**June-July-August**	**September-October-November**
Country:	0.66	8.85	19.05	10.64	-0.22	7.89	17.31	9.87	-0.67	7.83	17.94	10	-0.66	7.93	17.56	9.66
Highest:	6.64	14.52	25.09	16.59	5.95	13.64	23.41	15.9	5.61	13.58	24.06	16.11	5.47	13.73	23.69	15.83
Lowest:	-1.44	6.85	16.92	8.62	-2.31	5.91	15.19	7.85	-2.77	5.84	15.8	7.99	-2.68	5.96	15.47	7.67
	1991-2020				1961-1990				1960-1931				1930-1901			
Temperature average values-min	**December-January-February**	**March-April-May**	**June-July-August**	**September-October-November**	**December-January-February**	**March-April-May**	**June-July-August**	**September-October-November**	**December-January-February**	**March-April-May**	**June-July-August**	**September-October-November**	**December-January-February**	**March-April-May**	**June-July-August**	**September-October-November**
Country:	-2.9	4.35	13.69	6.27	-3.83	3.31	11.82	5.31	-4.32	3.24	12.37	5.5	-4.28	3.34	12.08	5.11
Highest:	2.69	9.77	19.46	11.91	1.93	8.78	17.59	10.97	1.48	8.69	18.13	11.23	1.46	8.87	17.87	10.9
Lowest:	-4.95	2.47	11.58	4.32	-5.87	1.45	9.74	3.34	-6.38	1.34	10.26	3.56	-6.24	1.49	10.04	3.16
	1991-2020				1961-1990				1960-1931				1930-1901			
Temperature average values-max	**December-January-February**	**March-April-May**	**June-July-August**	**September-October-November**	**December-January-February**	**March-April-May**	**June-July-August**	**September-October-November**	**December-January-February**	**March-April-May**	**June-July-August**	**September-October-November**	**December-January-February**	**March-April-May**	**June-July-August**	**September-October-November**

Country:	-2.9	4.35	13.69	6.27	-3.83	3.31	11.82	5.31	-4.32	3.24	12.37	5.5	-4.28	3.34	12.08	5.11
Highest:	2.69	9.77	19.46	11.91	1.93	8.78	17.59	10.97	1.48	8.69	18.13	11.23	1.46	8.87	17.87	10.9
Lowest:	-4.95	2.47	11.58	4.32	-5.87	1.45	9.74	3.34	-6.38	1.34	10.26	3.56	-6.24	1.49	10.04	3.16

From the temperature data analyzed and presented an increase in temperature over the last three decades of approximately 1°C has been observed, with a greater increase occurring in minimum average temperatures.

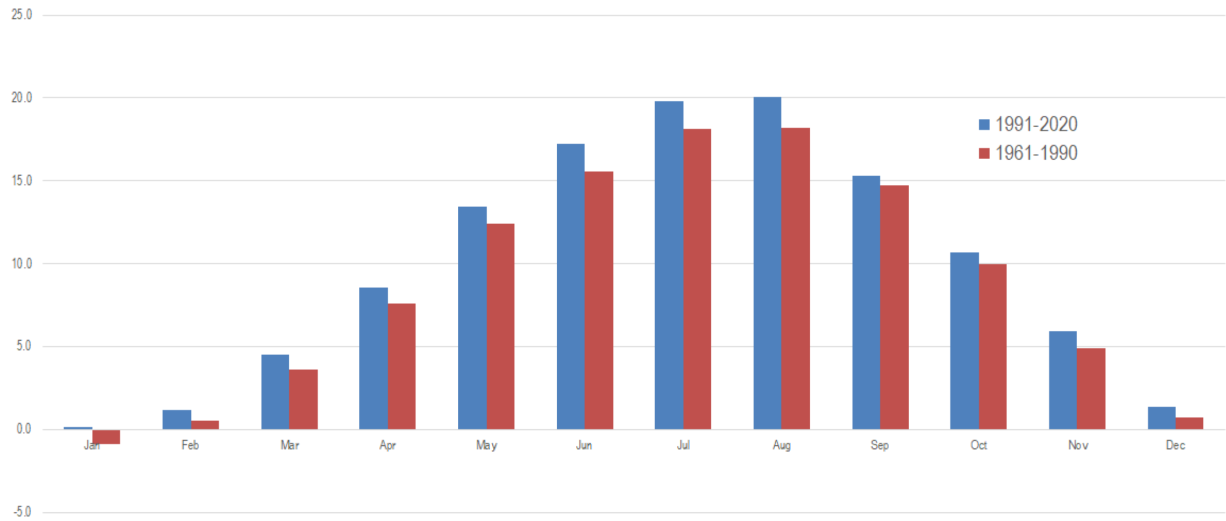


Figure 3 Monthly average temperatures (1991-2020, 1961-1990)

Regarding the temperature regime and obtained statistical trends it can be concluded that the trend presents significant temperature increase for all regions of Montenegro, with more emphasis in the last three decades.

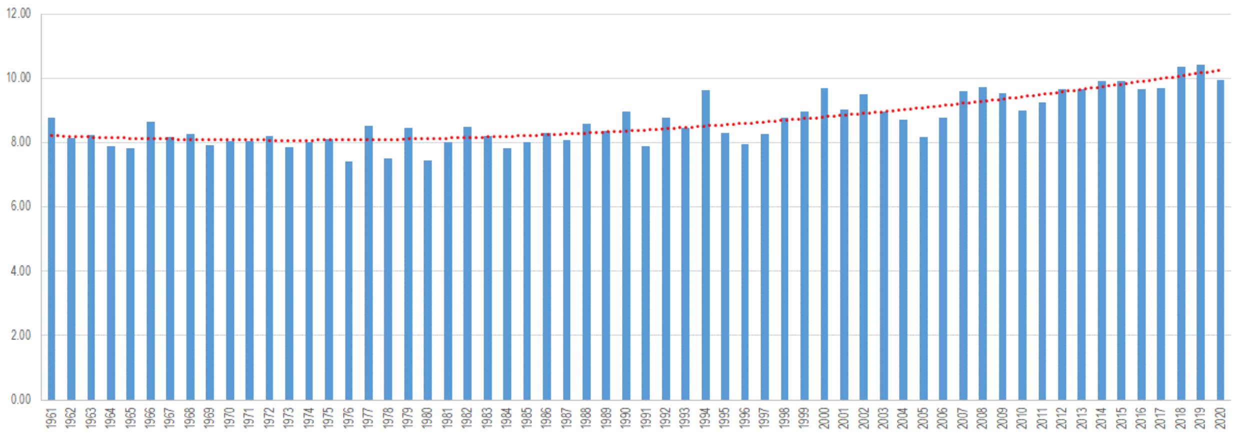


Figure 4 Annual average temperatures 1961-2020

In addition to the temperature, precipitation changes measured on several stations for the period 1961-2020 have been analyzed. Significant changes in the seasonal annual precipitation have not been observed for the period 1961-2020. The lowest annual amounts of precipitation occur in the period from 1980 to 2000, a period which according to the SPEI index is also characterized as a dry period.The number of days with more than 1 mm precipitation has significantly decreased, and the number of days with more than 40 mm has increased, however, indicating that climate has become drier and with more frequent extremely high daily sums (Burić and Doderović, 2021).

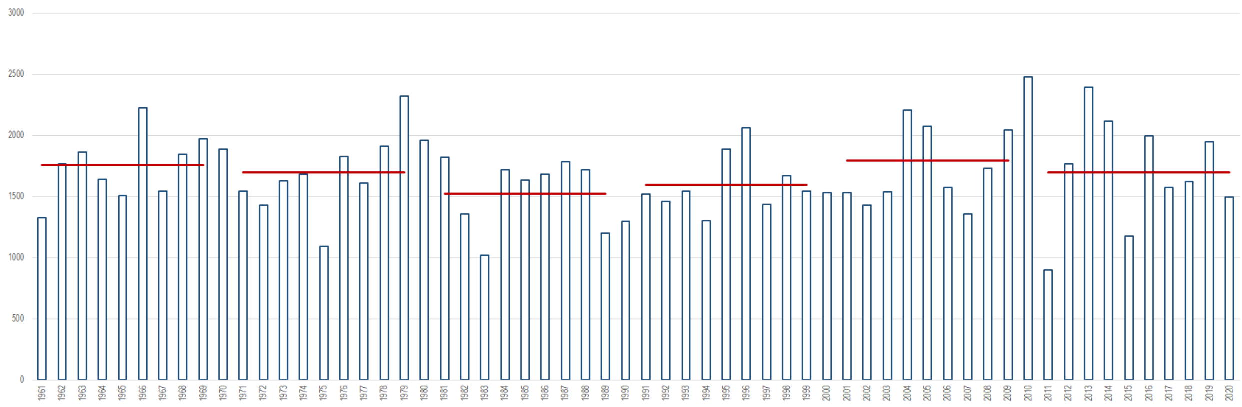


Figure 5 Annual precipitation sums for Podgorica

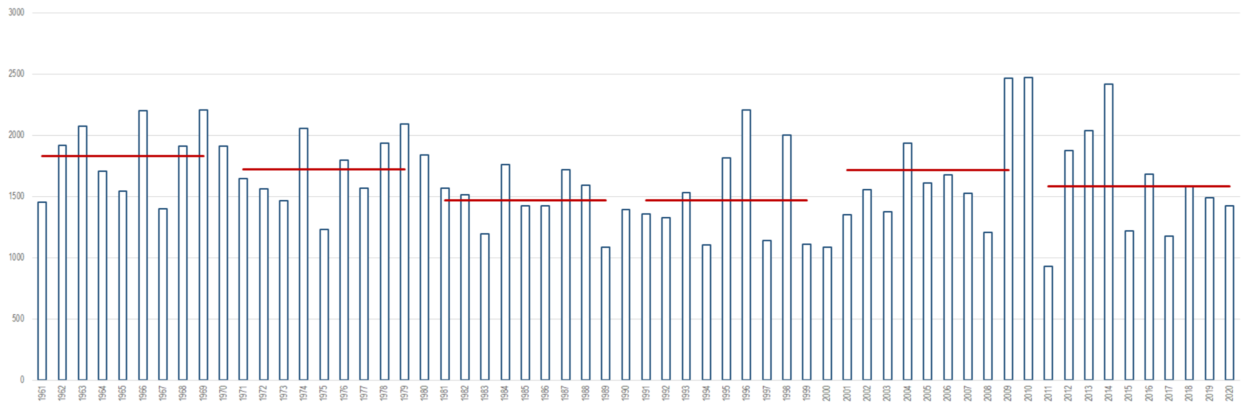


Figure 6 Annual precipitation sums for Tivat

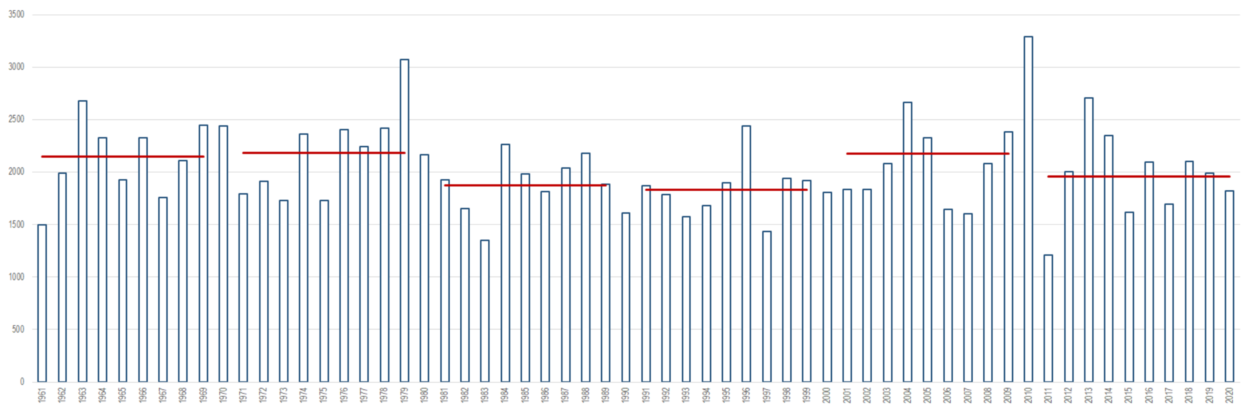


Figure 7 Annual precipitation sums for Niksic

Water Resources

Surface waters

The spatial arrangement of the surface water of Montenegro is primarily determined by the morphological and hydrogeological characteristics of the area. Water from the territory of Montenegro drains into two basins: the Adriatic Sea and the Black Sea. The Adriatic Sea Basin covers

45.4% and the Black Sea Basin 54.6% of the total territory of Montenegro. Generally speaking, both of these basins are rich in water, which on a global manner, makes Montenegro one of the richest countries with water.

The total area covered by the Black Sea Basin is about 7,545 km^2 [5]. Ibar, Lim, Cehotina, Tara and Piva are the main rivers within this basin.

The total area covered by the Adriatic Sea Basin is 6,268 km^2 [6]. Moraca, with its tributaries Zeta, Cijevna, Crnojevića and Orahovištica are main rivers of this basin. All these rivers first flow into Lake Skadar, and then the water moves along the river Bojana into the Adriatic Sea.

Based on applied approximate water balance of Montenegro, around 624 m^3/s of Montenegro waters run off from its territory. Transit waters make only an insignificant addition of 29 m^3/s to the total, so that domicile waters make up 95% of the total runoff from Montenegro territory. Considering basins, the Adriatic Basin although smaller than the Black Sea Basin, produces about 375 m^3/s, while the Black Sea runoff is around 249 m^3/s.

Ground waters

Ground water in Montenegro is present in rocks of different ages, from the Palaeozoic Era to the Quaternary Period. It is a very important resource that represents the only practical source of water for the population. In addition to supplying water to the population, ground water is also used in industry, as well as in agriculture. 75 sources are used to provide public water supplies to 40 urban settlements; 21 of these urban settlements are municipal centres and there are also a large number of suburbs. Of the total number of sources, ground water from karst aquifers is abstracted from 64 of them and ground water from inter-granular aquifers is abstracted from 11 sources.

Water use

Montenegro has significant surface and underground water resources, which are of relatively good quality[7]. The biggest consumers of water are industry and the population.

Statistical data show that in the period 2005–2020, the amount of water captured for the public water supply increased from 101.9 million m3 in 2005 to 121.3 million m3 in 2020, i.e. by 19%.

On the other hand, the water delivered to the final consumers is constantly decreasing. Of the total amount of water captured in 2020, it was delivered to the public water supply system 46.8 million m3, which is 13% less than in 2005 (53.67 million m3). In the observed period (2005–2020), losses in in the water distribution system increased from 47% (2005) to 61% (2020 years). According to the Energy and Water Regulatory Agency of Montenegro (REGAGEN), the non-revenue water on national level in 2020 is 67.14%.

Impounded waters from industry show a declining trend. The industry is only partially supplied with water from the public water supply and it is mostly supplied from its own water intakes, surface and underground. Water consumption in industry for the period 2006–2020 is shown in Figure below.

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[5] https://link.springer.com/content/pdf/10.1007%2F698_2019_413.pdf

[6] https://books.google.com/books?id=xTn1DwAAQBAJ

[7] the second national communication on climate change | unfccc https://unfccc.int/sites/default/files/resource/mnenc2_eng.pdf

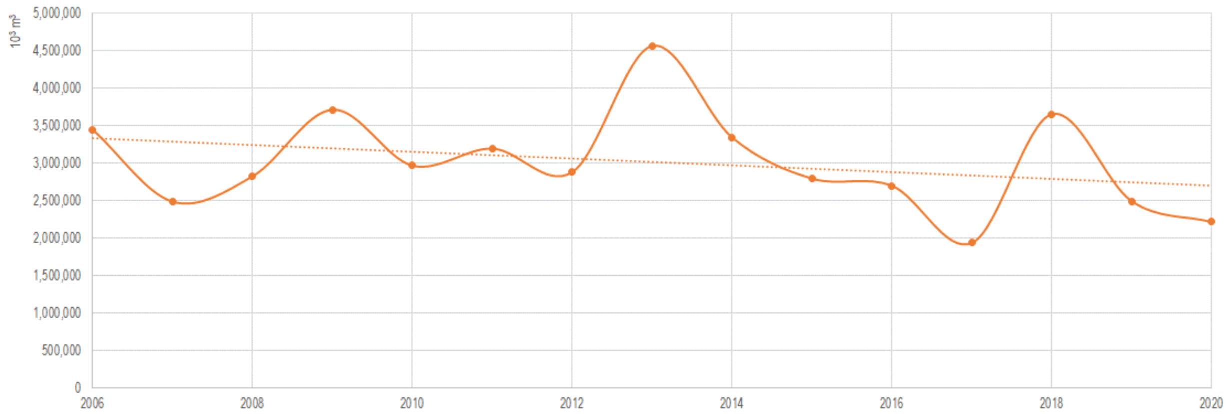

Figure 8 Water consumption in industry for the period 2006–2020

Of the total water used in industry, 99.27% is water used in the energy supply sector, while 0.73% is water used in the sectors mining and processing industry.

Mean Drought Index (SPEI)

Since the mid-80s, Montenegro is considered to face a dry period. An analysis of drought periods was performed for all water management regions, according to the SPEI drought index.

The Standardized Precipitation Evapotranspiration Index (SPEI), or Mean Drought Index, calculated for a 12-month period (SPEI 12 can maintain the long-term nature of precipitation, and can be related to flows, reservoir levels and groundwater levels for a longer time period), has been found to be closely related to drought impacts on ecosystems, crop, and water resources. The SPEI is designed to take into account both precipitation and potential evapotranspiration (PET) in determining drought[8].

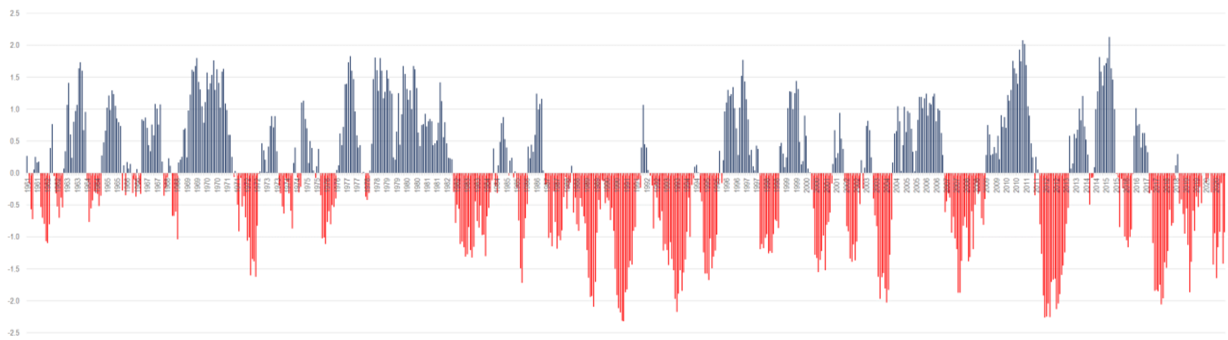

Figure 9 Standardized Precipitation Evapotranspiration Index SPEI 12

One method of accounting for antecedent precipitation is to sum the anomalies into a cumulative deviation or departure from mean (CDM[9]). CDMs have been used for some time in a range of scientific inquires and in professional reports and often yield is highly correlated to water resources variation.

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[8] Standardized Precipitation Evapotranspiration Index (SPEI) https://climatedataguide.ucar.edu/climate-data/standardized-precipitation-evapotranspiration-index-spei

[9] Mean precipitation (Pav) in a CDM, for a sequence of precipitation observations with time step i and length n, is calculated as Pav=1/n ∑_(i=1)^n▒Pi. The deviation Di is calculated for each time step by subtracting Pav from each observation in the period (Di=Pi-Pav), so that if Pi>Pav, the deviation Di is positive and if Pi<Pav then Di is negative. These values are then

The analysis of the long-term SPEI index, and its comparison with the cumulative anomalies of precipitation and temperature, indicates that from 1980 to 2000 there was a drastic decrease in precipitation, while from 2000 onwards, precipitation slowly normalized to the average multi-annual precipitation. In the same period the average temperature is constantly rising.

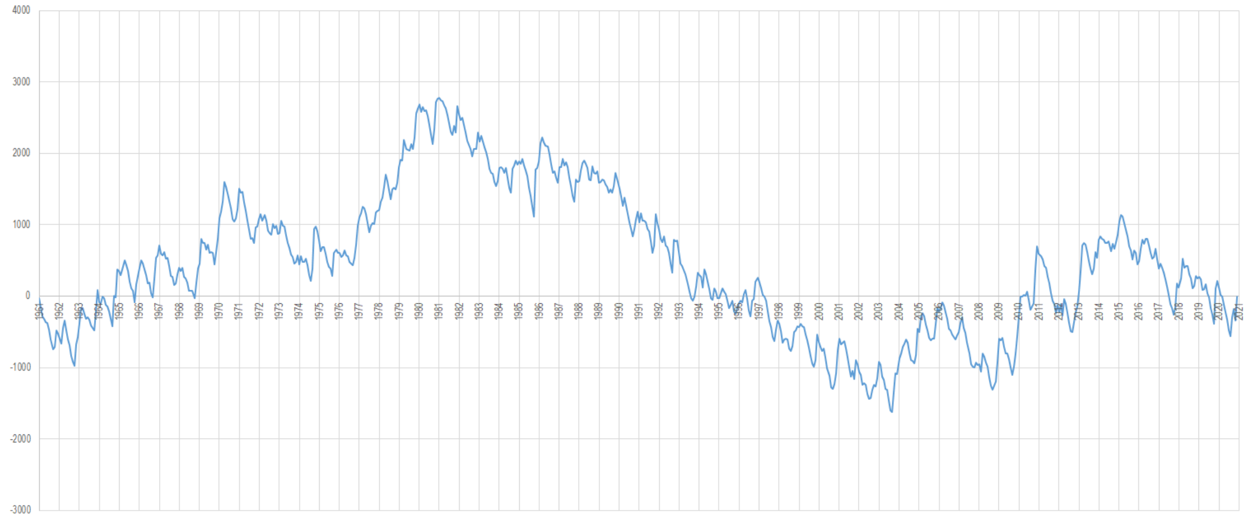


Figure 10 Cumulative precipitation anomalies for MS Niksic (mm)

To assess the impact of precipitation and temperature variations on surface water resources, the same methodology for cumulative runoff anomalies was performed for the hydrological observed discharges of the Morača River for the hydrological station in Podgorica. The analyzes show a high correlation between precipitation anomalies and surface water resource anomalies.

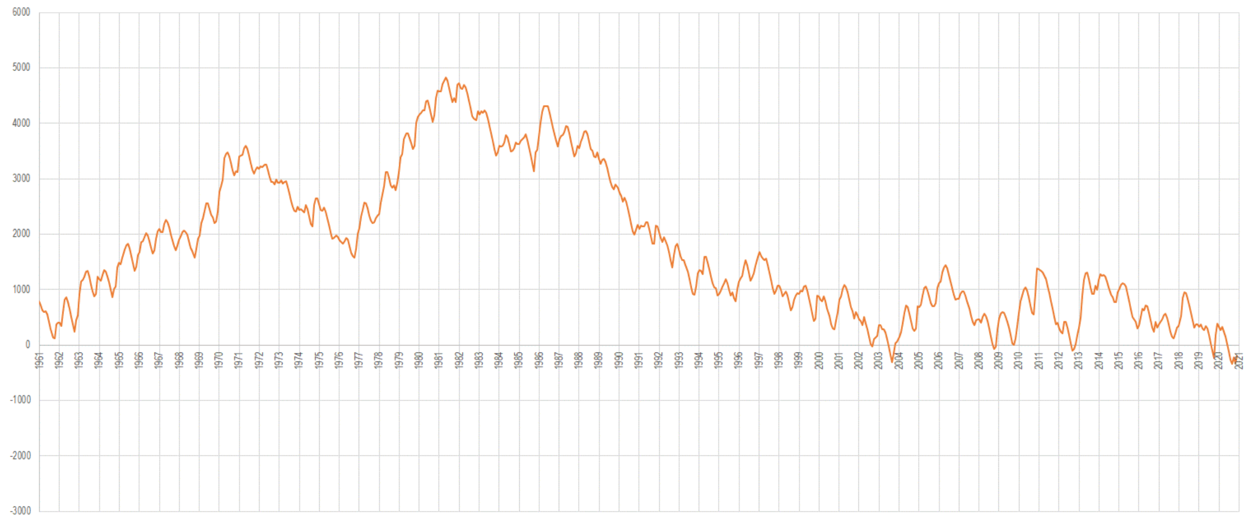


Figure 11 Cumulative discharge anomalies for HS Podgorica (m3/s)

summed in sequence CDMi=∑_(j=1)^i▒Di, yielding a time-series of the net surplus or deficit in precipitation at any point relative to the mean. In water budget terms, represents the deposits, whereas the represents the running balance at any point.

1.2. Socio-economic trends in the sector

Water sector is characterized by a number of specifics that are not found in others economic sectors. In principle, the water resources participate as a basic factor in all economic activities/sectors (such as **agriculture, energy, industry**).

Financing of the water sector in the current period of development of Montenegro has gone through several phases: budget financing, formation of water funds, formation of self-governing interest communities and formation of public companies that generate income through fees and contributions. The results of investments in certain periods are reflected in the developed management and protection systems, regional hydro systems and local hydro-technical measures and facilities.

Montenegro has 21 operators performing activities of public water supply and municipal wastewater management, as well as 2 operators performing exclusively the activity of wastewater treatment (LLC Wastewater Kotor-Tivat and LLC Wastewater Budva).

In Montenegro the water supply system prices are approved at local level each municipality. The Energy and Water Regulatory Agency in Montenegro issues approval on the tariff proposal and the final approval is given by the municipality.

In Montenegro there is fixed charge only for water supply meaning that fixed charges are applied in conjunction with volumetric tariffs. Calculation of the fixed charge takes into account the cost of maintenance, material cost except cost of electricity and fuel and costs for testing the water quality and number of customers.

According to the Law, infrastructure is owned by municipality, so municipality has obligation to invest in it.

The Law on Financing of Water Management determines the **sources of funds for financing water management**, the manner of calculation and payment of fees for the protection and use of water and water resources and other issues of importance for the provision and use of these funds.

Water charges are:

1) water use fee;
2) fee for protection of water from pollution;
3) fee for extracted material from watercourses.

Decisions on the payment of water fees are issued by the Water Administration. Information on collected water charges for 2017, 2018, 2019 and 2020 is given in Table xx:

Table 2 Information on collected water charges for 2017, 2018, 2019 and 2020

Year	Amount of fees for water use	Amount of fees for protection of water from pollution	Fee for material removed from watercourses	Total by years
2017	1.740.447,90	371.895,07	98.821,01	2.211,163,98
2018	1.891.285,78	481.321,56	177.457,46	2.550.164,80
2019	1.781. 896,88	495.630,59	56.242,79	2.333.770,26
2020	1.744.922,00	454.255,16	-	2.199.177,16
Total	7.158.652,56	1.803.102,38	333.521,26	9.294.276,20

The fee for protection of water from pollution is paid for direct or indirect pollution of the recipient's water in proportion to the degree of pollution of wastewater, ie other substances that worsen the quality of the recipient's water and the conditions of its use.

As it stated in Annual report on the comparison of business indicators of regulated utilities for 2020[10], published by The Energy and Water Regulatory Agency of Montenegro in November 2021, the level of non-revenue water[11] at the level of Montenegro in 2020 was at a slightly higher level compared to 2019 - from 66.16% in 2019 it increased to 67.14% in 2020, which is a negative trend.

A significant change in the level of non-revenue water compared to 2019 is evident in WS Budva, where there was an increase in this indicator by 10.91%, from 53.82% in 2019 to 64.73% in 2020. This increase can be attributed to significantly lower amounts of invoiced water in 2020, as a result of reduced water consumption due to the COVID-19 pandemic.

Non-revenue water per user per month in 2020 at the level of Montenegro amounted to 25.15 m^3 / user / month.

Compared to 2019, the average number of breakdowns per kilometres of water supply network at the level of Montenegro in 2020 increased by 26% and amounts to 4.37 breakdowns / km.

The level of coverage of the population in the country with public sewage network is 53.71% in 2020, which is 3.64% more than in the previous year.

The collection rate for 2020 at the level of Montenegro is 88.76%, which is a significant decrease compared to 2019 (9.60%). For most performers, the level of collection is lower compared to 2019, due to the reduction of purchasing power of users as a consequence of COVID-19.

Required amounts of water

The required quantities of water for public water supply for the ten-year and twenty-year planning period were determined by the Strategy for water management until 2035, on the basis of demographic indicators, projections of the degree of connection to the system (current and projected) and projected specific consumption.

Demographic projections until the end of the planning period show a very small percentage of population growth at the state level, resulting in a small increase in public water supply users.

The required quantities of water for public water supply for the ten-year and twenty-year planning period were determined on the basis of demographic indicators, projections of the degree of connection to the system (current and projected) and projected specific consumption.

Table 3 Connection of the population to the public water supply

Region	Population number	Degree of connection %	Number of customers

[10]Annual report on the comparison of business indicators of regulated utilities for 2020, https://regagen.co.me/komunalne-djelatnosti/benchmarking-komunalne-djelatnosti/izvjestaji/

[11] The calculation of the level of non-revenue water is done on the basis of data on the amount of water produced and the amount of invoiced water.

Year	2015	2025	2035	2015	2025	2035	2015	2025	2035
South region	150653	156130	160539	89	95	100	134081	148323	**160539**
Middle region	298316	315926	328985	87	93	98	259535	293811	**322405**
North region	172841	157099	149590	63	85	90	108890	133534	**134631**
Montenegro	**621810**	**629156**	**639115**	**79**	**91**	**96**	**491230**	**572532**	**613550**

Another very important segment of water as basic element for production is **energy sector**. **Based on the current hydrological study of the network of surface watercourses, it is stated that the water quantity of the Montenegrin water bodies is disproportionally big in comparison with the relatively small area of the territory of Montenegro. The huge quantities and the quality of the surface water bodies results in significant water potential, which can be transformed into hydropower potential.**

Table 4 Hydropower potential along the main watercourses of Montenegro

River	Power (MW)	Energy (GWh/annualy)
Piva	155	**1361**
Tara	257	**2255**
Ćehotina	53	**463**
Lim	164	**1438**
Ibar	14	**118**
Morača do Zete	168	**1469**
Zeta	229	**2007**
Mala rijeka	52	**452**
Cijevna	32	**283**
Total:	**1.124**	**9.846**

Table 5 Theoretical and technical hydropotential in Montenegro:

Teoretical potential	Technical potential
Main water courses: 9,8 TWh	**Main water courses: 3,7 - 4,6 TWh**
Small water courses : 0,8-1,0 TWh	**Small water courses: 0,4 TWh**
Total: 10,6 – 10,8 TWh	**Total: 4,1-5,0 TWh**

Analyzing the already existing installed energy production capacities, the current energy mix of Montenegro is represented by **hydropower plants** with 67.06% (702.895 MW), thermal power plants with 21.47% (225 MW), wind power plants with 11.26% (118 MW), and solar power plants with 0.21% (2.233 MW).).

2. Overview of the climate adaptation planning processes in Montenegro

2.1. Overall climate adaptation planning process

The assessment of climate adaptation in the relevant sectoral and climate protection legislation has concluded that there is no legally established framework for climate adaptation planning in the country, despite the existence of various Laws and planning processes that somehow relate to climate change adaptation. The assessment has resulted in the following specific conclusions:

- The Law on climate protection of Montenegro (Article 5) recognises the National Adaptation Plan (in the further text NAP) as basis climate planning instrument and defines the minimum content of the NAP.

- According to the prescribed minimum content of the NAP in the Law (Article 9), the NAP would also need to define the institutional framework for climate adaptation in the country.

- The Law doesn't prescribe mechanisms for cross-sectoral policy alignment and mainstreaming of the adaptation priorities in the sectoral policies and plans.

- The Law doesn't prescribe climate change coordination mechanism as for example National Climate Change Committee, Climate Council or Sustainable development council.

- The Government of Montenegro (GoM) supported by international organisations have taken steps to develop a long-term adaptation planning process in the process of the preparation of the National Climate Change Strategy by 2030 and the preparation of the Third National Communication. However, all these processes have been project based and haven't been institutionalised and legally established.

- The National Climate Strategy by 2030 has been prepared in 2013 and its content is not aligned with the latest EU requirements for long term strategic planning for climate action defined in the Regulation 1999/2018 (the Energy Governance Regulation).

- Despite the fact that the National Climate Strategy by 2030 has adaptation aspects into its content, the document only provided an overview of the internationally recommended approaches for climate adaptation, and provides information on the preparatory elements and the processes essential for the development and implementation of the NAP. The table containing the preparatory elements and the process for development and implementation of the NAP is well elaborated, but it is general for all sectors and it doesn't set clear responsibilities for specific institutions, timelines and institutionalised coordination mechanism needed for implementation of such steps in a form of a specific action plans.

- In addition, the National Climate Strategy by 2030 provides an overview of the proposed adaptation measures by sectors as defined in the draft Second National Communication, which are not sufficiently described, and the process of identification of the vulnerabilities and definition of this measures is not elaborated.

- The TNC of Montenegro prepared in 2020 in its Sector vulnerability and adaptation analysis provides very clear recommendation that the priority activity for climate adaptation is the strengthening of the strategic planning for climate change adaptation at the local and regional levels, as well as in the sector-level planning process. In addition the TNC recommends this to be accomplished through the development of action plans for climate change adaptation at the local and regional levels, development of action plans for climate change adaptation of vulnerable sectors, integration of adaptation measures in strategic and development documents, preparation of plans for the prevention of climate change impacts in sectors vulnerable to climate change, and through the development of methods and standards for implementation of adaptation measures. Also, an additional proposed measure is strengthening of local and regional governments and other relevant national, regional, and local stakeholders regarding climate change adaptation. These measures are very valid, but again, they don't describe and prescribe the national coordination mechanism for climate adaptation, the legal and the institutional aspects for establishment of such mechanism, as well as the processes and the responsibilities for climate change adaptation on national and local level.

- Despite the fact that in the framework of the TNC a vulnerability assessment and adaptation measures for all priority sectors has been done, the adaptation planning process done in the framework of the preparation of the TNC is not prescribed and responsible stakeholders and processes for coordination, elaboration, implementation and monitoring of the climate adaptation are not defined.

- Montenegro's Updated NDC provides a development framework and guidance for more ambitious adaptation goals to be developed under the project "Enhancing Montenegro's capacity to integrate climate change risks into planning". According to the Updated NDC, the goals defined by the NDC will have a clear effect on project activities focusing on addressing the gaps of an underperforming coordination framework, the lack of institutional capacity, the insufficient information and lack of finance to fund adaptation investments and will also improve the capacity of the private sector to understand and respond to climate vulnerabilities and risks.

Taking into consideration all conclusions listed above, one of priorities of the NAP Project should be to define, legally regulate and institutionalise the national climate adaptation planning processes.

2.2. Assessment of the sectoral planning process

Institutionally, the Ministry of Agriculture, Forestry and Water Management is responsible for developing policy in water management and protection of water from pollution. The Ministry of Ecology, Spatial Planning and Urbanism is responsible for wastewater management, utility services and coordinating regional water supply systems[12]. The Ministry of Health is responsible for the health safety of water for human consumption, giving opinions on its safety.

[12] The Energy and Water Regulatory Agency of Montenegro https://www.wareg.org/articles/the-energy-and-water-regulatory-agency-of-montenegro-regagen/

Local governments regulate and ensure the performance and development of utility services, maintenance of communal facilities, prescribe in more detail the conditions and manner of providing water supply and wastewater management services to local operators.

For the water resources sector there is not a formally established climate adaptation planning process. The coordination and the adaptation planning are also done on an ad-hoc or project driven bases, with no clearly defined stakeholders, roles and responsibilities.

Montenegro has adopted several documents (strategies, plans, action plans), which define protection and rescue - reducing the risk of natural disasters with relations to water resources, but without a formal approach to climate change adaptation.

There is number of policy and assessment documents relevant for the sector water resources which are published in Montenegro. Twelve basic data sources containing data on water regime, climate and climate change (atlases, strategies, plans, reports, books) have been assessed, eleven scientific publications by M. Buric, and eight documents obtained from UNDP.

Below this text is a list of policy documents for the water sector and an overview of the climate change consideration in this specific documents.

Water Management Strategy

It includes the regulation of basins, achieving good water status and protection, ensuring sufficient quantities of water for water supply, sustainability of the water sector, the establishment of measuring and management and IT support.

Projection of long-term water supply of Montenegro until 2040

Legislative, strategic and institutional framework, state and sources of water supply.

Adaptation to Climate Change, Montenegro (Report)

The document provides an overview of the status of climate change adaptation policy and its implementation in Montenegro. The aim of the report was to strengthen public participation in climate change decision-making, as well as to examine the impacts of climate change, define vulnerabilities to those impacts and summarize adaptation measures to climate change.

Second National Communication on Climate Change of Montenegro to the United Nations Framework Convention on Climate Change (UNFCCC), 2013

Detailed assessment of the water sector and proposal of the water cadastre in Montenegro, which includes review of hydrometeorological network, review of availability and needs of geographic data, conceptual design for national water information system (water cadastre), review of data coordination in the water sector and work process, climate change to the water regime of the Lim and Tara rivers basins.

Third National Report on Climate Change in Montenegro

Provides overview of the vulnerability of surface waters to climate change, the vulnerability of groundwater to climate change, water balance analysis and the like.

National Climate Change Strategy 2015-2030

Chapter 6 provides an overview of the basic envisaged adjustment measures by sector (water resources).

Water Management Plan in the Danube River Basin

Legal and institutional framework for water management; General description of the characteristics of the river basin district; Summary of significant pressures and impacts of human activity on surface water and groundwater status; Identification and mapping of protected areas; Map of monitoring networks; Status of surface water bodies and groundwater bodies; Review of measures required for the implementation of legislation; Water protection communities.

Water Management Plan in the Adriatic Basin

Legal and institutional framework for water management; General description of the characteristics of the river basin district; Summary of significant pressures and impacts of human activity on surface water and groundwater status; Identification and mapping of protected areas; Map of monitoring networks; Status of surface water bodies and groundwater bodies; Review of measures required for the implementation of legislation; Water protection communities; National strategic goals for water and connection with the Water Basin Management Plan of the Danube Basin.

3. Data constrains, gaps and reccomendations

3.1. Gaps in sectoral information for gender sensitive vulnerability assessment of the water sector

It can be generally concluded that the key national policies in Montenegro dealing with water on one hand[13], and gender-related policies on the other are lacking the gender dimension in correlation to the water sector, as well as are lacking sex-disaggregated data.

The intersection of gender and climate change policies must be strengthened in Montenegro, along with strengthening the institutional capacities on intersecting gender and climate change at policy development level, as well as implementation level, and accompanied by gathering sex-disaggregated data and development of gender indicators for the purpose of gender responsive measurement and verification of the climate actions

Multiple indicators cluster survey in 2019 (MONSTAT) represents the main source of data in order to define the access to water services on the base of a household level.

Still, sex-disaggregated data in the water sector are missing on the policy, program and project level.

It has to be emphasized that gender-based vulnerabilities in the climate adaptation context (and in climate change context in general) are based on intersection of different types of gendered and climate vulnerabilities, and therefore have to be cross-referenced in order to define the gendered vulnerabilities in climate adaptation context.

It can be concluded that there is a total absence of sex-disaggregated data in the water sector in the context of climate vulnerability and climate change adaptation. Recalling the Universal`s Declaration of Human Rights "right to water and sanitation" it is highly recommended in future the design and collection of sex-disaggregated data and gender indicators in this sector to be included in the agenda., for the purposes of designing sustainable and efficient adaptation activities dealing with gendered vulnerabilities.

3.3. Reccomendation for improved data collection and management of gender sensitive climate relevant data for the water sector

- Water utilities should urgently take measures to improve the quality of data by measuring the amount of affected water, establish measurement of water consumption, continuously record and enter data on utility infrastructure into the Geographic Information System (GIS), record and classify failures that occur on the infrastructure, record the reasons and duration of all interruptions in the provision of services to customers, collect data on customer complaints, etc.

[13] - Law on Providing Healthy Water for Human Use, 2021, Law on Waters, 2018 and Law on Regional Water Supply of the Montenegrin Coast, 2016 are not gender sensitive. Water Management Strategy 2016-2035 sets the following goals that are implicitly gender responsive (but have to be more explicitly defined): Ensuring sufficient quantities of water of adequate quality for water supply of population and all the needs of the economy; Protection of the population and material goods from floods and other forms of harmful effects of water; Involving the public in the process of adopting strategic determinants of integral development of water management systems.

- An important measure to protect drinking water sources is to make and implement decisions on sanitary zone protection. Despite the existing legal provisions, according to the Water Directorate, only 49 of about 90 wells have been designated as sanitary protection zones. In addition, where the process of defining protection zones has been carried out, problems are often noted with the lack of data that should help in defining and establishing protection zones, especially in defining a wider protection zone of a source that coincides with a source basin.
- In order to increase the degree of connection of the population to the public sewerage system, the biggest challenge will be to provide financial resources for the construction of a new and expansion of the existing sewerage network, since there is a big disproportion between the level of water supply and sewerage network.
- Gender responsive coherence, governance and operational procedures in the water sector: Development of institutional structure (in a form of procedures) for sex-disaggregated data collection on policy, program, project level in water sector in order to identify gender gaps in in the needs as well as the level of inequality in the access to adaptation services and resources;
- Creation of the set of gender-sensitive indicators based on the existing practices on collecting sex-disaggregated data upgraded with the international sets of gender indicators (SDGs);
- Capacity building on the methods and instruments for collecting sex-disaggregated data, as well as monitoring and reporting through design of gender indicators.
- Monitoring and reporting: Development of institutional structure (in a form of procedures) for monitoring progress on gender equality and women's empowerment and tracking gender-differentiated results.

4. Findings on sectoral risks, vulnerabilities and impacts from the past and the present climate variability in Montenegro

4.1. Observed impacts on the sector water resources

Water sector is vulnerable to projected changes in mean climate conditions such as mean temperature and rainfall, projected climate variability (climate variability is expected to increase in a warmer climate), as well as projected changes in the frequency and intensity of extreme weather events and changes in the sea level.

Concern about the potential effects of climate change on water resources is growing. Water resources vulnerability is a critical issue to be faced by society in the near future[14]. Current variability and future climate change are affecting water supply and demand over all water-using sectors. Consequently, water scarcity is increasing.

Climatic, hydrological, geological and socio-economic factors influencing vulnerability need to be identified and appropriate indicators selected[15]. Exposure, sensitivity, potential impact and adaptive capacity (Figure 1) are all considered in the evaluation of vulnerability to a defined climate change stressor such as temperature and precipitation.

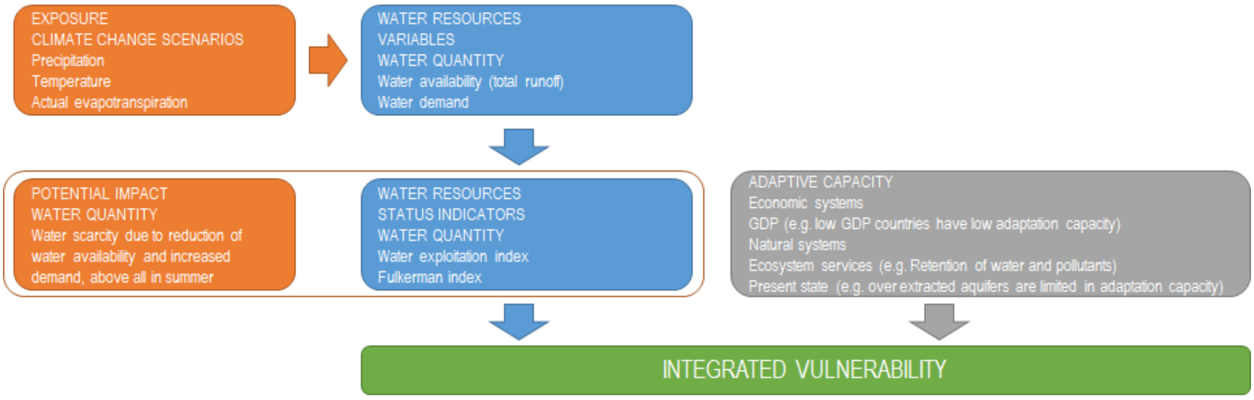


Figure 12 Components of Vulnerability

The potential impacts of climate change on the WSS sector are presented in Figure bellow:

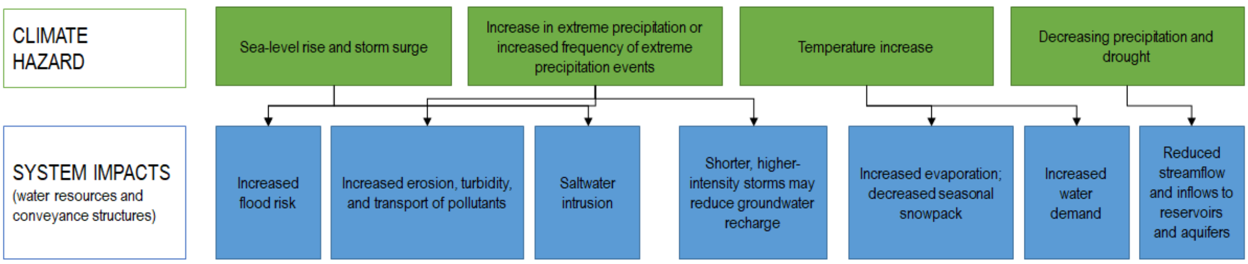


Figure 13 Potential impacts of climate change on the WSS sector

[14] http://drinkadria.fgg.uni-lj.si/externalapp/content/outputs/WP4/FB8_FB5_Common%20methodology%20for%20WR%20vulnerability_act4.4.1.pdf/
[15] https://moam.info/cc-ware-south-east-europe-programme_5a1066b31723dd1b91a4e99e.html

The largest floods in Montenegro since the half of the past century until now have occurred in: 1963, 1979, 1999, 2000, 2010 and 2011. Although Montenegro can be exposed to all kinds of floods, two categories of floods are characteristic: (1) Fluvial floods which are result of abundant rain series of a few days with a large amount of rainfall, which in extreme cases can reach about 500~1000 lit/m2, covering larger space and (2) Meteorological floods (pluvial and flash floods) which are local; they are more likely to occur and they are related to torrents and urban environments or a certain fragment of space.

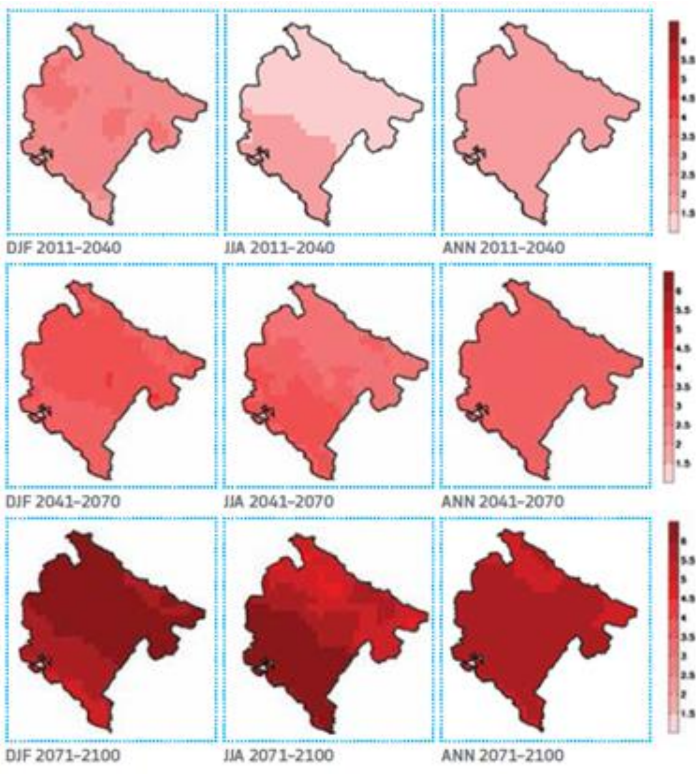
Climate change projections

Projections of future climate change in Montenegro are taken from the Third National Communication on climate change (2020). These data are spatially distributed and added to the catchment areas within the Black Sea and Adriatic basins.

The results from the climate projections show an increase in the annual temperature of 1.5° C to 2° C by 2040 throughout the country. The increase in the temperature during the winter months December–January–February is expected to be between 2° C and 2.5° C, and in the summer months June–July–August it is expected to be on average around 2° C.

For the period 2041–2070 the deviations of the mean annual temperature range from 2.5° C to 3° C. The predicted warming in winter and summer is on average the same, with a more prominent increase in the north in winter and in the south in summer.

For the period 2017–2100, the deviation in the mean annual temperature over most of the territory is around 5.5° C. During the winter, the projected increase in temperature is expected to exceed 6° C in the northern mountain areas, while during the summer it will be higher with 6° C in the southern, coastal part, at lower altitudes.



River Basin	T_JJA2011–2040	T _JJA_2041–2070	T_JJA_2071–2100
Boka Bay	2.0	3.0	6.0
Cehotina	1.5	2.5	5.5
Drina	1.5	2.5	5.5
Ibar	1.5	2.5	5.5
Lake Skadar/Shkoder	2.0	3.0	6.0
Lim, Drina	1.5	2.5	5.5
Morača and Zeta	1.5	2.5	5.5
Piva, Drina	1.5	2.5	5.5
Tara	1.5	2.5	5.5
Trebišnjica, Gatačko Polje	2.0	3.0	6.0
Ulcinj - Budva	2.0	3.0	6.0

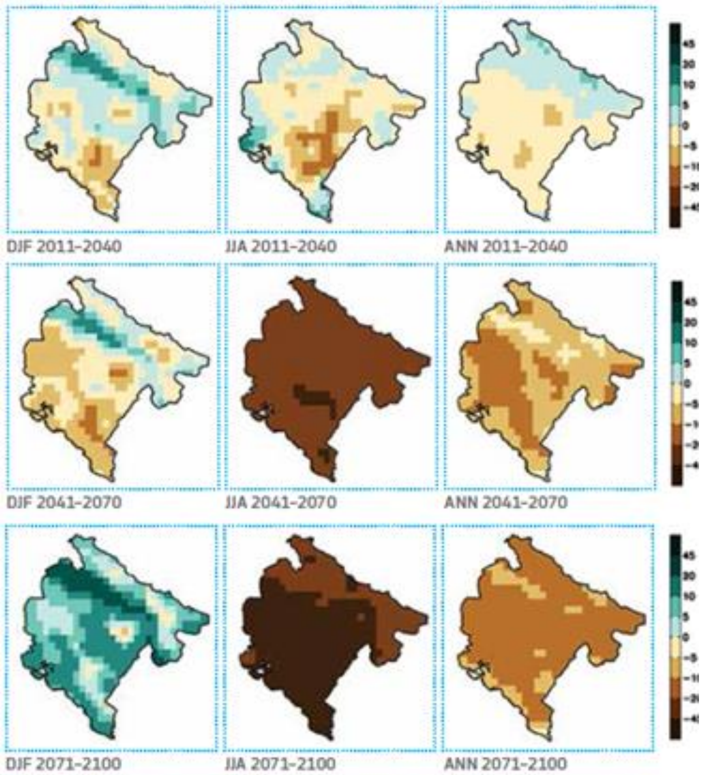
Figure 14 Change (° C) of the mean winter (December-January-February), summer (June-July-August), and annual (ANN) temperatures, for the periods 2011–2040, 2041–2070, and 2071–2100, compared to the period 1971–2000, according to scenario RCP8.5

The results from the climate projections show a decrease in rainfall especially during the summer months and increase in winter months in some parts of the country.

For the period 2011–2040, the north of the country is expected to experience an increase in rainfall of up to +5%, while in the southern part of the country the rainfall it is expected to decrease by up to −5%. For the December-January-February season, rainfall is expected to increase by up to +5%, with a slightly more pronounced change in the north, while for the June-July-August season the rainfall is expected to decrease slightly, especially in the southeast regions.

For the period 2041–2070, the country is expected to experience a decrease of up to 20% in the mean annual rainfall throughout the territory. The changes during the winter are similar to the annual deviations during the period 2011–2040, while the summer season is characterized by a decrease of rainfall of up to −45%.

For the period 2017–2100, the mean annual rainfall is expected to decrease by up to −20% over most of the country. The rainfall can be expected to increase by about +20% on average in winter, while in summer there is a clear decrease with values more than −45%.



River Basin	P_ANN2011–2040	P _ANN_2041–2070	P_ANN_2071–2100
Boka Bay	-5.0	-10.0	-20.0
Cehotina	5.0	-10.0	-20.0
Drina	5.0	-10.0	-20.0
Ibar	5.0	-10.0	-20.0
Lake Skadar/Shkoder	-5.0	-10.0	-20.0
Lim, Drina	5.0	-10.0	-20.0
Morača and Zeta	-5.0	-10.0	-20.0
Piva, Drina	5.0	-20.0	-20.0
Tara	5.0	-5.0	-10.0
Trebišnjica, Gatačko Polje	-5.0	-20.0	-20.0
Ulcinj - Budva	-5.0	-10.0	-10.0

River Basin	P_JJA2011–2040	P _JJA_2041–2070	P_JJA_2071–2100
Boka Bay	-5.0	-30.0	-45.0
Cehotina	-5.0	-30.0	-30.0
Drina	2.0	-30.0	-30.0
Ibar	-2.0	-30.0	-30.0
Lake Skadar/Shkoder	2.0	-30.0	-45.0
Lim, Drina	-2.0	-30.0	-45.0
Morača and Zeta	-7.0	-45.0	-45.0
Piva, Drina	2.0	-30.0	-45.0
Tara	2.0	-30.0	-30.0
Trebišnjica, Gatačko Polje	5.0	-30.0	-45.0
Ulcinj - Budva	-2.0	-30.0	-45.0

Figure 15 Change (%) in the mean winter (December-January-February), summer (June-July-August) and annual (ANN) precipitation accumulation, for the periods 2011–2040, 2041–2070, and 2071–2100 compared to the period 1971–2000, according to scenario RCP8.5

4.2. Risk metrics - criteria and indicators needed for the prioritization exercise

Changes in mean climate conditions, climate variability, and climate extremes could impact the water sector in diverse ways, including direct and indirect physical impacts and a variety of nonphysical impacts.

Climate risk screening and project impact assessment together establish the climate change vulnerability context[16]. That context informs the adaptation assessment that follows, which aims to identify those measures best suited to reduce climate vulnerability, thereby establishing a direct link between specific project activities and the overall objective of reducing climate vulnerability.

The decision matrix below illustrate the process of identifying project vulnerabilities and adaptation options for projects involving water resources and conveyance structures.

These decision matrix primarily focus on the potential direct and indirect physical impacts of climate change on water resources.

[16] https://can-adapt.ca/knowledge-base/climate-services/water-sector-climate-change-adaptation

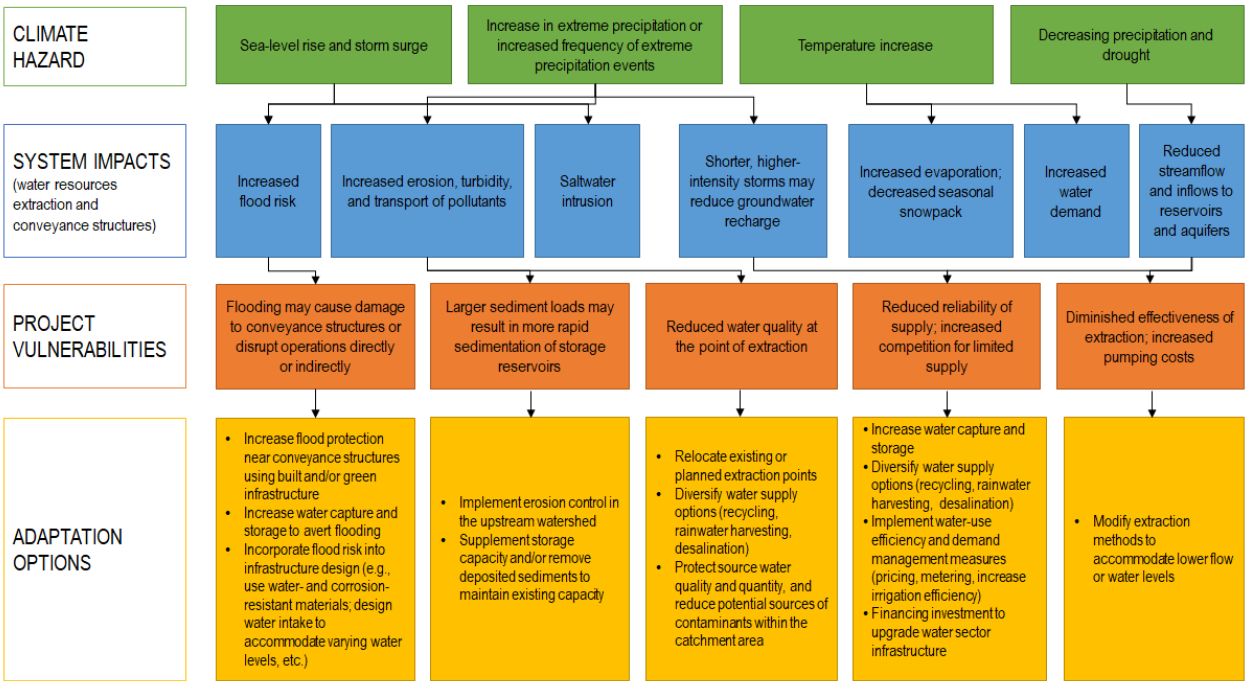


Figure 16 Decision matrix

The above decision matrix offer an initial, non-exhaustive list of potential adaptation options for addressing particular climate impacts. Because this matrix applies to measures involving physical assets, many of the options identified are structural or physical adaptation options. Such options are often referred to as "hard" adaptation options. They involve on-the-ground physical infrastructure and technical equipment, like additional water storage capacity or reconstruction of existing water related facilities. Structural adaptation options also include a variety of ecosystem- or nature-based adaptation measures.

There are also a variety of nonstructural (or "soft") adaptation options. Some of them, according to the recommendations of the Water Management Strategy in Montenegro (2017-2035) and the Third National Communication on climate change (2020), are listed below:

- Applying an integrated approach to water resources and systems management, and a strengthening of cross-sector planning and activities
- Increased public motivation and ensured its involvement in all phases of planning in the water sector
- Improving the efficiency and cost-effectiveness of water services (nonrevenue water levels have to be lowered by improving the quality of metering devices and reducing network leakage through sound maintenance and renewal of assets)
- Implementing sound cost recovery principles (tariffs may need to be reviewed according to sound cost recovery principles, especially since the investments to upgrade the existing infrastructure will generate an increase in operational costs

Based on all previously carried out analyses, recommendations and conclusions, and in line with Sustainable Development Goals (SDGs) which are developed in a way to ensure interconnections between the environmental, economic and social aspects of development, to assess the vulnerability of the sector leading to future climate change, the following indicators are proposed. Based on the analyzes from this report and other relevant sources, the base value is given for all the proposed indicators.

Table 6 Indicators for assessment of the vulnerability of the water sector

Indicator	Description, Benchmarks	Baseline
Available internal freshwater resources	It quantifies the components of the hydrologic cycle and a water balance equation based on the law of conservation of mass	18,754 10^6 m^3
Available total freshwater resources	It quantifies the components of the hydrologic cycle and a water balance equation based on the law of conservation of mass	19,669 10^6 m^3
Water withdrawal per capita	Agriculture, Industry (mining and quarrying, manufacturing, constructions) and Municipal includes service sectors	246 m^3/capita
Level of water stress: freshwater withdrawal as a proportion of available freshwater resources[17]	Water exploitation index shows the mean annual total demand for freshwater divided by the long-term average freshwater resources. It gives an indication of how the total water demand puts pressure on the water resource	~1%
Level of water stress: available freshwater resources per capita	It relates the total freshwater resources with the total population in a country and indicates the pressure that population puts on water resources, including the needs for natural ecosystems[18]	31,688 m^3/capita
Water-use efficiency over time	Losses in in the public water distribution system (baseline scenario from REGAGEN)	67.14%
Degree of integrated water resources management implementation	Enabling environment, Institutions and participation, Management instruments and Financing[19]	Overall score 35%
Proportion of bodies of water with good ambient water quality in Montenegro[20]	Percentage of monitored water bodies in a country with good ambient water quality.	88%
Proportion of transboundary basin area with an	Transboundary river and lake basins, Transboundary aquifers	Overall score 67

[17] SDG-indicator 6.4.2 Metadata - UN Statistics Division https://unstats.un.org/sdgs/metadata/files/metadata-06-04-02.pdf
[18] State of Climate Services Report 2021: WMO - Drishti IAS https://www.drishtiias.com/daily-updates/daily-news-analysis/state-of-climate-services-report-2021-wmo/print_manually
[19] Indicator 6.5.1 | UNEP - UN Environment Programme https://wesr.unep.org/article/indicator-651
[20] Montenegro - Country (or area) | SDG 6 Data https://www.sdg6data.org/country-or-are

operational arrangement for water cooperation[21]		
Spatial extent of water-related ecosystems	Spatial extent of lakes, rivers, estuaries, and artificial water bodies	263 km^2

4.2. Vulnerability assessment, mapping and modeling

Water resources vulnerability to climate change

According to UNEP methodology (2009), vulnerability is a function of water availability, use and management parameters. One of the parameters is water exploitation index (WEI) or water stress, which is the ratio of total water demand (domestic, industrial and agricultural) to the available amount of renewable water resources that consists of surface water and groundwater safe yield (river discharge or runoff and groundwater recharge). Values from 0.2 to 0.4 indicate medium to high stress, whereas values greater than 0.4 reflect conditions of severe water limitations (Vorosmarty et al.2000).

Water demand is estimated as water withdrawal by sectors. Future water demand can be estimated regarding population growth (domestic water use), GDP changes (industrial water use) and land use changes (agricultural water use). Nevertheless, all these are also subject to policy. Future water demand will be assessed applying different scenarios. Uncertainty can be expressed as differences among min, plausible and max values.

Methodological approaches for vulnerability assessments

In order to assess the vulnerability of the water sector to the various climatic variables, the following analyzes were carried out as part of this assessment:

- Water balance/budget assessment, represents quantification of Montenegro's waters, which is sought to be carried out by analysis and comparison of water availability against water use/demand data, including climate change effects. The scope of the water balance modelling is to assess the hydrological potential of the sub-basins within Montenegro, according to the following approach:
    1) Consolidation of existing meteorological, hydrological and water demand data; identification of data gaps and approaches to improving the overall data situation;
    2) Simulation of the entire set of sub-basins in current conditions;
    3) Simulation of the entire set of sub-basins, impacted by the climatic projections identified for future conditions;
    4) Definition of the water available for each sub-basin;
    5) Assessment of change in annual discharge between the present situation and medium/long-term future in the Montenegro catchments,
    6) Assessment of change in seasonal discharge between the present situation (and medium/long-term future in the Montenegro catchments and
    7) Water Scarcity Assessment - analysis of temporal and spatial indicators-metrics for physical water scarcity assessment
- Water Footprint (WF). In general, practically all economic sectors depend on water to a certain extent. Nevertheless, clearly, some sectors are more water-dependent than others. Water

[21] Indicator 6.5.2 "Proportion of transboundary basin area with ...https://www.unwater.org/our-work/integrated-monitoring-initiative-sdg-6/indicator-652-proportion-transboundary-basin-area

Footprint (WF) is another concept that is used to establish a better understanding of the critical role of water resources for country's water security and resilience to climate change. It is defined as the total volume of water used for production of the goods and services consumed by an individual, community or business, however covering the whole process from manufacturing raw materials to direct operations, and consumer use of a product. The WF assessment is presented in Chapter 1.3 of this report, as an essential assessment for examination of the critical role of the water resources in the national economy, sustainability and security.

- Vulnerability assessment of floods through the integration of spatial and economic modelling, and
- Susceptibility assessment of torrential floods

Water quantity indicators for vulnerability assessment

Variables and indicators for water quantity sensitivity to climate change are presented in the table below. Water quantity indicators were calculated for the present and future (2011-2040, 2041-2070 and 2071-2100) periods. As climate change data, results from Montenegro Third National Communication on Climate Change were used.

Table 7 Variables and indicators for water quantity.

	Variables and indicators	Symbol	Units	DATA SOURCES & FORMULAS
Variables	Precipitation	Vul	$10^6 m^3$/year	WMSM, ZHMS CG
	Actual evapotranspiration	Wisp	$10^6 m^3$/year	WMSM
	Water demand - total	WD	$10^6 m^3$/year	WD=DWD+AWD+IWD
	Water demand – domestic	DWD	$10^6 m^3$/year	Monstat, IBNET, WSC, Regagen
	Water demand-agriculture	AWD	$10^6 m^3$/year	Monstat, WMSM
	Water demand – industry	IWD	$10^6 m^3$/year	Monstat, IBNET, WSC, Regagen
Indicators	Total Runoff	Wot	$10^6 m^3$/year	Wot=Vul-Wisp
	Water Exploitation Index	WEI	NA	WEI=WD/Wot
	Water Surplus	WS	$10^6 m^3$/year	WS=Wot–WD
	Water stress index	WSI	$10^6 m^3$/yr/capita	WSI=Wot/population

Generally, all indicators are calculated as long term mean annual values. To account for uneven seasonal distribution of water demand and water availability, a seasonal water exploitation index is additionally considered (summer period).

4.2.1. Water balance/budget (Total runoff)

Current situation

Water budget is an accounting of the inputs and outputs of water in a hydrologic system. It quantifies the components of the hydrologic cycle and a water balance equation based on the law of conservation of mass. The results provide insight into how water moves in the watershed and are useful for the management of water quantity.

The conceptual water budget is developed by using of measured and calculated inputs and outputs of a hydrologic system. Inputs are the processes that add water to the system; these include precipitation and inflow from surface water and groundwater. Outputs are the processes that remove water from the system; these include evapotranspiration and outflow from surface water and groundwater.

Water availability was calculated as a simplified water budget (water budget equation relates the inputs and outputs of a hydrologic system mathematically according to the law of conservation of mass):

Wot = Vul – Wisp + ΔS

Where Wot is total runoff (surface and groundwater), Vul is precipitation, Wisp is actual evapotranspiration and ΔS is a storage change term. Since long term annual values are used, the storage term ΔS is neglected.

Based on applied hydrological and climate processing and analysis, the approximate water balance of Montenegrin watersheds, from the Water Management Strategy in Montenegro (2017-2035) was used.

From these analyzes, it is evident that around 595 m3/s of Montenegro's own waters run off from its territory (out of total runoff 624 m3/s). This is equivalent to a runoff volume of about 18.75 billion m3/year (19.67 billion m3/year total runoff volume). Transit waters make only an insignificant addition of 29 m3/s to the total, so that domicile waters make up 95% of the total runoff from Montenegro.

The Adriatic Basin (6,268 km2), although smaller than the Black Sea Basin (7,545 km2), produces about 11.35 billion m3/year, which is about 50% more in terms of runoff than the Black Sea runoff (7.4 billion m3/year).

The total runoff volume from Montenegro territory is 19.67 billion m3/year (11.81 billion m3/year from the Adriatic Basin and 7.86 billion m3/year from the Black Sea Basin). In the Adriatic basin, the Skadar basin plays a dominant role, while in the Black Sea basin most dominated are Tara, Lim and Piva basins.

Table 8 Data for the ground water bodies in Montenegro

Parameters	Avl	Atr	Vvl	Vtr	Vul	Wvl	Wtr	Wot	Wisp	Wuk
River	**(km^2)**	**(km^2)**	**(10^6 m^3)**	**(10^6 m^3)**	**(10^6 m^3)**	**(10^6 m^3)**	**(10^6 m^3)**	**(10^6 m^3)**	**(10^6 m^3)**	**(10^6 m^3)**
Ibar	433	0	423	0	423	188	0	**188**	235	423
Lim	2,291	270	3,001	272	3,274	1,910	272	**2,182**	1,091	3,274

Ćehotina	1,113	16	1,043	7	1,050	538	7	**546**	505	1,050
Tara	1,915	125	3,261	95	3,356	2,450	95	**2,545**	811	3,356
Piva	1,731	53	2,976	79	3,055	2,292	79	**2,372**	683	3,055
Rest	62	0	55	0	55	22	0	**22**	33	55
Black Sea basin	**7,545**	**464**	**10,759**	**453**	**11,213**	**7,401**	**451**	**7,855**	**3,358**	**11,213**
Morača and Zeta	2,649	0	6,194	0	6,194	5,096	0	**5,096**	1,097	6,194
Skadar Lake	1,624	225	3,653	461	4,114	2,671	461	**3,133**	981	4,114
Ulcinj - Budva	656	0	1,191	0	1,191	883	0	**883**	308	1,191
Boka Bay	728	0	2,258	0	2,258	1,892	0	**1,892**	365	2,258
Trebišnjica,Gatačko Polje	541	0	936	0	936	755	0	**755**	181	936
Rest	70	0	84	0	84	55	0	**55**	29	84
Adriatic Sea Basin	**6,268**	**225**	**14,315**	**461**	**14,776**	**11,353**	**461**	**11,814**	**2,962**	**14,776**
Total (Montenegro)	**13,813**	**689**	**25,074**	**915**	**25,989**	**18,754**	**915**	**19,669**	**6,320**	**25,989**

Where: Avl area of own basin, Atr area of the basin outside Montenegrin borders, Vvl precipitation volume on the basin inside Montenegrin territory, Vtr precipitation volume on the basin outside Montenegrin territory, Vul total volume of precipitation, Wvl runoff from Montenegrin territory, Wtr runoff from areas outside Montenegrin territory, Wot total runoff volume, Wisp evaporation volume, Wuk total water balance.

4.2.2. Water balance/budget (Total runoff) under climate change

The climate is the main natural driver of the variability in the water resources, and atmospheric precipitation, air temperature and evapotranspiration are commonly used for assessing and forecasting the water availability.

The values of RCP8.5 scenario for possible climate changes in Montenegro, are entered in the historical climate data series, new sequences are generated and then again is carried out the calculation of water budget.

To the water budget from the Water Management Strategy in Montenegro (2017-2035), which represents a base (current) scenario, changes in precipitation and changes in temperatures reflected by changes in actual evapotranspiration have been added, for the three reference periods 2011-2040, 2041-2070 and 2071-2100.

The analyzes were carried out on an annual basis, as well as for the summer period (June, July and August).

Table 9 Volume of total annual and June-July-August season volumes of precipitation

Parameters	Baseline scenario	2011-2041	2041-2070	2071-2100
	Annual			
River	(10^6 m^3)	(10^6 m^3)	(10^6 m^3)	(10^6 m^3)
Ibar	423	444	381	338
Lim	3,274	3,438	2,947	2,619
Ćehotina	1,050	1,103	945	840
Tara	3,356	3,524	3,188	3,020
Piva	3,055	3,208	2,444	2,444
Rest	55	58	49	45
Black Sea basin	**11,213**	**11,774**	**9,953**	**9,307**
Morača and Zeta	6,194	5,884	5,575	4,955
Skadar Lake	4,114	3,908	3,703	3,291
Ulcinj - Budva	1,191	1,131	1,072	1,072
Boka Bay	2,258	2,145	2,032	1,806
Trebišnjica,Gatačko Polje	936	889	749	749
Rest	84	80	74	69
Adriatic Sea Basin	**14,777**	**14,038**	**13,204**	**11,942**
Total (Montenegro)	**25,990**	**25,812**	**23,157**	**21,249**
	Summer period (June-July-August)			
Danube River (Black Sea) basin	2,803	2,804	1,962	1,724
Adriatic Sea Basin	1,847	1,792	1,177	1,016
Total (Montenegro)	4,650	4,595	3,139	2,740

Table 10 Wisp - total annual and June-July-August season volumes of actual evapotranspiration

Parameters	Baseline scenario	2011-2041	2041-2070	2071-2100
	Annual			
River	(10^6 m^3)	(10^6 m^3)	(10^6 m^3)	(10^6 m^3)
Ibar	235	250	256	271
Lim	1,091	1,158	1,189	1,271
Ćehotina	505	537	551	584
Tara	811	864	888	943

Piva	683	725	745	796
Rest	33	35	36	38
Black Sea basin	**3,358**	**3,570**	**3,666**	**3,903**
Morača and Zeta	1,097	1,162	1,191	1,270
Skadar Lake	981	1,032	1,055	1,119
Ulcinj - Budva	308	324	331	348
Boka Bay	365	384	392	416
Trebišnjica,Gatačko Polje	181	192	197	210
Rest	29	31	31	33
Adriatic Sea Basin	**2,962**	**3,123**	**3,197**	**3,396**
Total (Montenegro)	**6,320**	**6,693**	**6,863**	**7,298**
	Summer period (JUNE-JULY-AUGUST)			
Danube River (Black Sea) basin	1,576	1,645	1,687	1,801
Adriatic Sea Basin	602	627	641	679
Total (Montenegro)	2,178	2,272	2,328	2,479

Table 11 Wot - total annual and June-July-August season runoff volume

Parameters	**Baseline scenario**	**2011-2041**	**2041-2070**	**2071-2100**
	Annual			
River	**(10^6 m^3)**	**(10^6 m^3)**	**(10^6 m^3)**	**(10^6 m^3)**
Ibar	188	195	125	67
Lim	2,183	2,279	1,758	1,348
Ćehotina	545	566	394	256
Tara	2,545	2,659	2,300	2,078
Piva	2,372	2,482	1,699	1,648
Rest	22	23	13	7
Black Sea basin	**7,855**	**8,204**	**6,288**	**5,404**
Morača and Zeta	5,097	4,723	4,384	3,685
Skadar Lake	3,133	2,877	2,648	2,173
Ulcinj - Budva	883	808	741	724
Boka Bay	1,893	1,761	1,640	1,390
Trebišnjica,Gatačko Polje	755	698	552	539

Rest	55	49	43	36
Adriatic Sea Basin	**11,815**	**10,915**	**10,007**	**8,547**
Total (Montenegro)	**19,670**	**19,119**	**16,294**	**13,951**
	Summer period (JUNE-JULY-AUGUST)			
Danube River (Black Sea) basin	1,227	1,159	275	-76
Adriatic Sea Basin	1,245	1,165	536	337
Total (Montenegro)	2,472	2,324	811	261

Possible climate changes that are expected in the future, resulting in decrease of precipitation and increasing of actual evapotranspiration (and modification of their time distribution), may cause decreasing of average annual flow of 30% by the end of the 21st century. In the summer period, these changes are even more drastic and result in a water deficit in some of the sub-basins.

Water demand

Total water demand (WD) was evaluated as the sum of domestic (DWD), agricultural (AGRWD) and industrial (INDWD) water demand:

WD = DWD + AGRWD + INDWD.

All water demand data have units million m^3/year. Data sets of WD were provided on municipal level based on several sources (Monstat, IBNET, Water Supplying Companies and Regagen), and for conducting the analysis of the vulnerability of water resources through the water balance, the data were transferred to hydrological units - water basins.

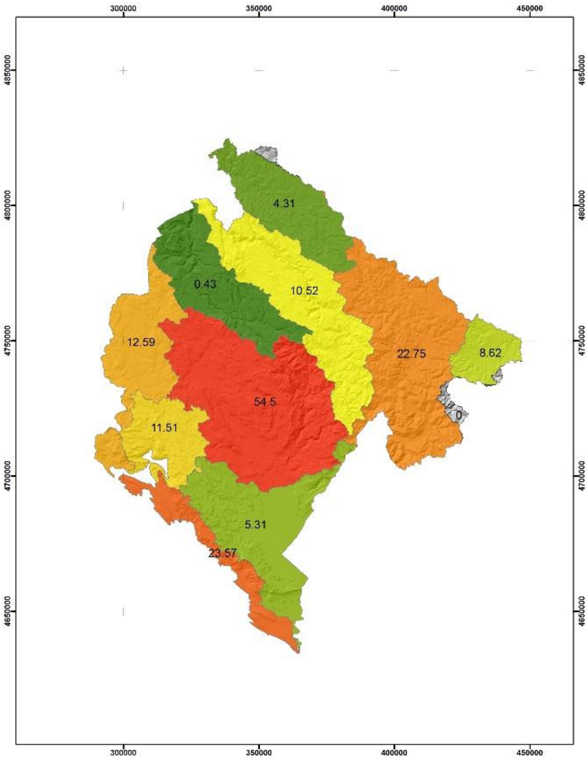


Figure 17 Total annual water demand $10^6 m3$

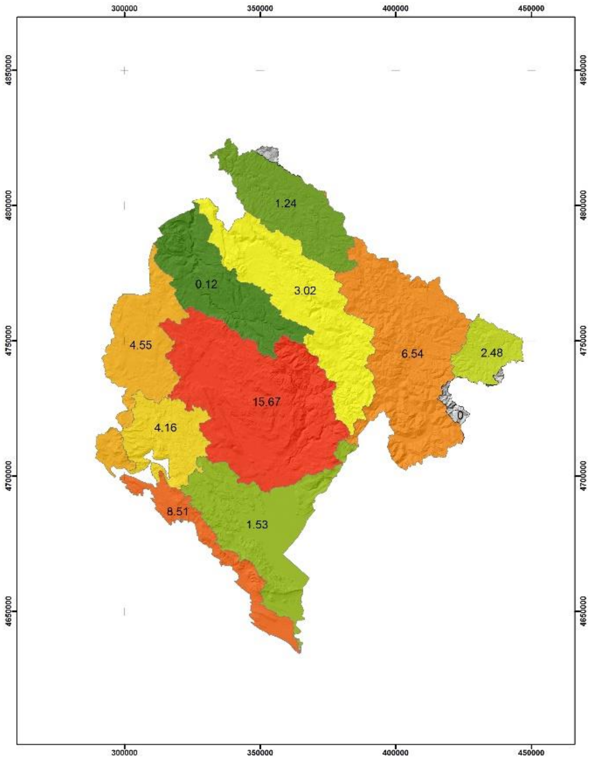


Figure 18 Total summer season water demand $10^6 m3$

The largest consumption of water is in the basin of Zeta and Moraca, followed by the basins of Ulcinj-Budva and Lim.

Water exploitation index (WEI)

Water exploitation index is a “less is better” type indicator. This index shows the mean annual total demand for freshwater divided by the long-term average freshwater resources. It gives an indication of how the total water demand puts pressure on the water resource (Environmental European Agency, 2021).

From water demand WD datasets and total runoff Wot, WATER EXPLOITATION INDEX (WEI) can be calculated as a ratio between annual WD and Wot for all periods and scenarios, presented in GIS model in Figure 11:

$$WEI = \frac{WD}{Wot} = \frac{\mathrm{DWD + AGRWD + INDWDV}}{\mathrm{Vul - Wisp} + \Delta \mathrm{S}}$$

The indicator presents the annual total freshwater abstraction in a country as a percentage of its long-term annual average available water from renewable freshwater resources.

Total freshwater abstraction includes water removed from any fresh water source, either permanently or temporarily. Mine water and drainage water as well as water abstractions from precipitation are included, whereas water used for hydroelectricity generation (in situ use) is excluded[22].

[22] https://ec.europa.eu/eurostat/databrowser/product/page/t2020_rd220

The warning threshold of 20% for this indicator distinguishes a non-stressed from a water scarce region, with severe scarcity occurring where the WEI exceeds 40%.

Assessing the WEI on an annual basis would show no substantial deficits, as the mean water demand is lower than availability. Also assessing the WEI on an annual basis neglects seasonality and extremes in demand and availability. These factors are however frequent causes for water scarcity and need to be addressed.

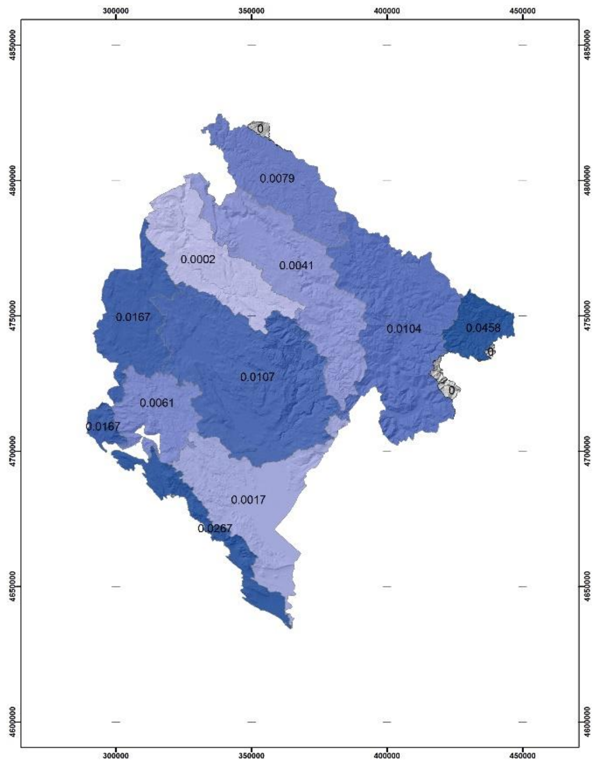


Figure 19 Annual Water exploitation index, current state

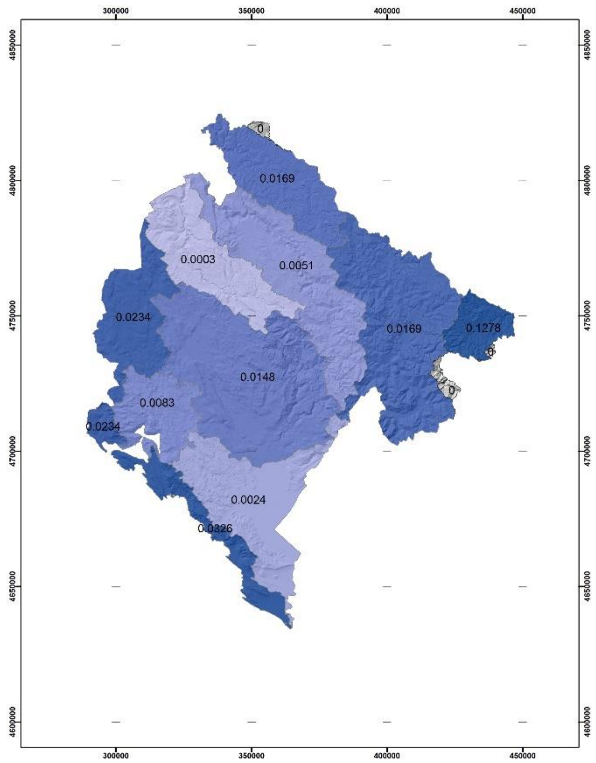


Figure 20 Annual Water exploitation index, RCP-8.5 2071-2100

Not counting water for hydropower production, WEI for Montenegro is about 1% (as one of the Indicators of SDG 6 - Ensure availability and sustainable management of water and sanitation for all). Major changes of this indicator on annual basis are not expected in the future period either. In some European countries, such as Cyprus, Malta, Spain and Italy, the WSI ranges from 25% to 45%.

WEIs for summer months present the worst-case scenarios regarding water stress, which are very important in water resources management, since in summer season water demand is much higher and droughts are more frequent in the last decades. Analyzes show that a significant number of watersheds in the future may face water stress in the summer months under the influence of climate change and increased water consumption.

Water Surplus (WS)

Annual and seasonal surplus of water resources is calculated as the difference of total runoff and water demand:

WS = Wout – WD

Annual surplus of water resources per sub-basins (LWS) for baseline and future period under climate change is presented in figure bellow. A significant reduction of water surplus can be observed in some of the basins compared with the baseline scenario. A WS simulation was also made with an increase in water consumption (water demand) at the level of the entire country by 50% by the end of the century. In such a scenario, the reduction of excess water in some of the basins is drastic and reaches up to 70%.

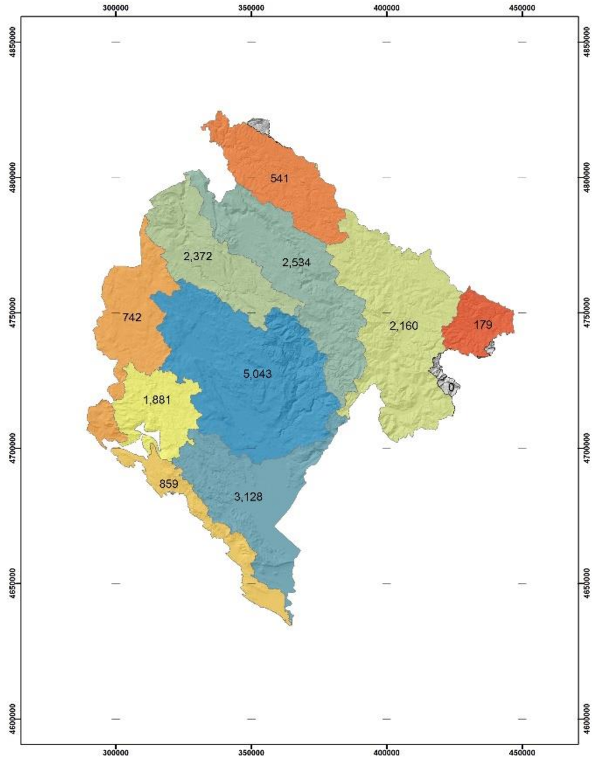


Figure 21 Annual Water surplus106m3, current state

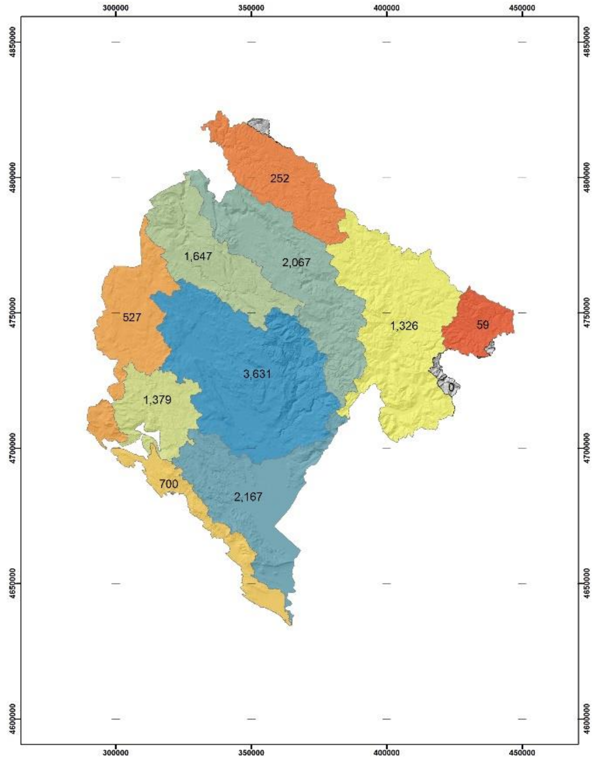


Figure 22 Annual Water surplus106m3, RCP-8.5 2071-2100

Water stress index (Falkenmark WSI)

WSI represents renewable freshwater resources per inhabitant. This is a “more is better” type indicator (+) and represents the availability of water per capita.

The Falkenmark indicator is one of the most widespread used indicators for assessing the stress on water. It relates the total freshwater resources with the total population in a country and indicates the pressure that population puts on water resources, including the needs for natural ecosystems.

Falkenmark developed this indicator on the grounds of a minimum need of 100 l/day/cap for household use and from 5 to 20 times as much as for agricultural and industrial uses (Hinrichsen et al., 1998). The threshold for this indicator is that water stress begins at less than 1700 m3/cap/year (Cosgrove et al., 2000). When the indicator drops below 1 000 m3/cap/yr, the country can face water scarcity (Hinrichsen et al., 1998).

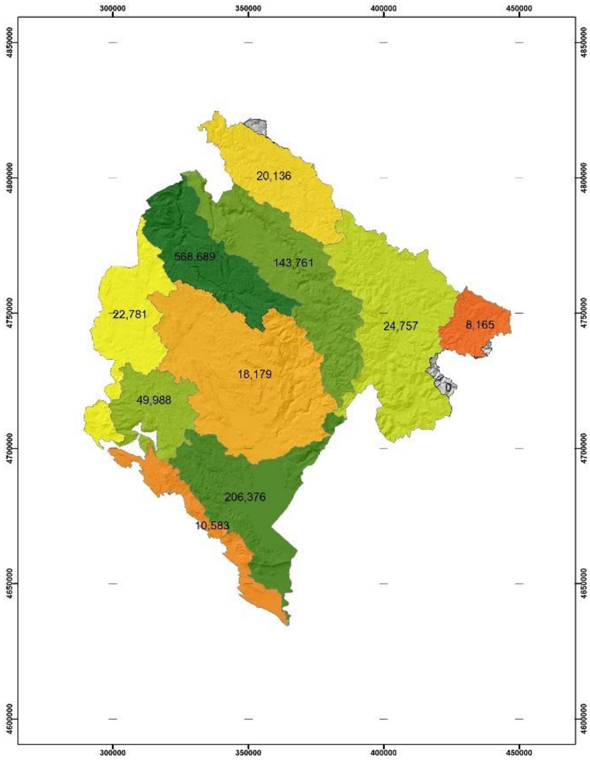


Figure 23 Annual Water surplus10^{6}m3, current state

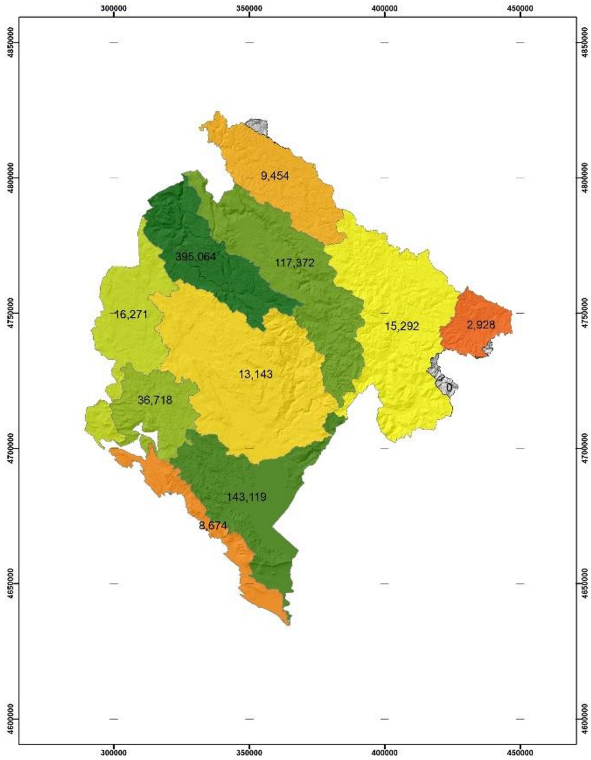


Figure 24 Annual Water surplus10^{6}m3, RCP-8.5 2071-2100

The amount of available renewable water sources per inhabitant in Montenegro is 31,700 m^3/capita/year. Under the influence of possible climate changes, these quantities are expected to be reduced to 22,500 m^3/capita/year without future population growth.

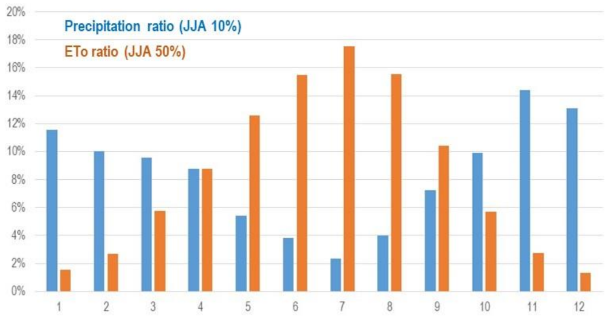
Within EU, five countries (Denmark, Czech Rep, Belgium, Malta and Cyprus) have less than 1700 m^3/cap/year according to the 2001 data. The two latter can be considered as facing water scarcity (< 1000 m^3/cap/year). Within the Balkan region, Serbia and Kosovo have less than 1700 m^3/cap/year according to the 2020 data based on available internal freshwater resources.

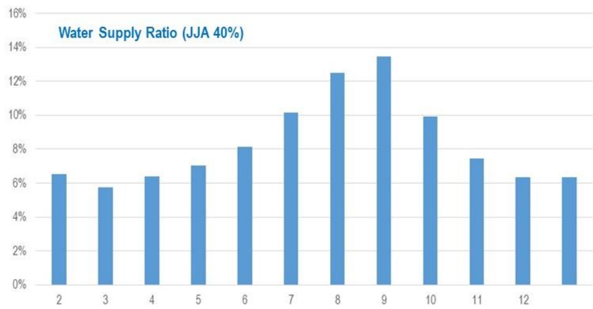
Results interpretation and conclusions

Possible climate changes that are expected in the future, resulting in decrease of precipitation and increasing of actual evapotranspiration (and modification of their time distribution), may cause decreasing of average annual flow of 30% by the end of the 21st century. In the summer period, these changes are even more drastic and result in a water deficit in some of the sub-basins.

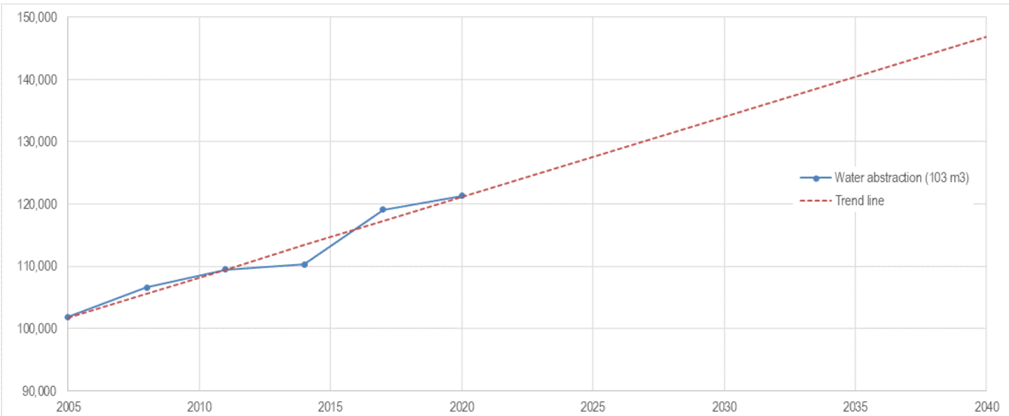
In the summer months, precipitation accounts for only 10-15% of the total annual precipitation, and evapotranspiration accounts for 45-50%. On the other hand, water consumption is significantly higher in the summer months and accounts for ~35-40% of the total annual consumption.

According to the climate change scenarios, during the summer months in the future, a decrease in precipitation of 30 to 50% is expected depending on the region, and an increase in temperature by 5.5-6.0 oC, which is directly reflected in an additional increase of evapotranspiration.





A water surplus simulation was also made with an increase in water consumption (water demand) at the level of the entire country by 50% by the end of the century. Although this increase seems relatively high, it may not be so far from reality. Statistical data (and REGAGEN report for 2020 based on analysis of all communal utilities in Montenegro) show that in the period 2005–2020, the amount of water captured for the public water supply increased from 101.9 million m3 in 2005 to 121.3 million m3 in 2020, i.e. by 19% (1.3% annually). If this trend continues in the future in combination with the increase in temperatures that directly affect water consumption, perhaps until the end of the considered period, this assumption will come true. In such a scenario, the reduction of excess water in some of the basins is drastic and reaches up to 70%.



It is widely agreed that land use change and climate variability are two active environmental factors profoundly affecting watershed hydrology. Land use changes, which are mostly induced by human activities, affect hydrological processes such as evapotranspiration (ET), interception and infiltration, resulting in alterations of surface and subsurface flows[23]. Climate variability also brings distinct changes to hydrological regimes and influences spatial and temporal patterns of water resources in a region.

Land use and climate change can accelerate the depletion of freshwater resources that support humans and ecosystem services on a global scale. Land uses that impact water resources include agriculture, forestry, urbanization, recreation, and industrialization[24].

[23] Hydrological Impacts of Land Use Change and Climate ... – NCBI https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4922588/

[24] How do changes in land use impact water resources?the lowe https://www.americangeosciences.org/critical-issues/faq/how-do-changes-land-use-impact-water-resources

Comparing two analytical periods of CLC changes (2000 and 2018), shows a slightly increasing trend in intensity of landscape development in Montenegro.

Artificial development shows an extensive increasing trend, with an annual land take rate of 0.51%, which is one of the highest rates in Europe.

- Artificial surfaces in Montenegro have changed by 9.094% in the period 2000-2018 (EU28 average 6.295%)
- Wetlands in Montenegro have changed by -0.12% in the period 2000-2018 (EU28 average -0.414%)
- Water bodies in Montenegro have changed by -0.151% in the period 2000-2018 (EU28 average 1.052%)
- Forest and semi natural areas in Montenegro have changed by -0.143% in the period 2000-2018 (EU28 average -0.064%)
- Agricultural areas in Montenegro have changed by -0.288% in the period 2000-2018 (EU28 average -0.617)

Below are listed some measures in accordance with the Water Framework Directive that are linked to distinct water bodies, as well as with identified drivers, significant pressures and impacts;

Policy and regulatory measures are considered those measures that either come out as requirements of the legislation or this analisis (e.g. Improvement of water quantity and quality monitoring system, Adopting new water pricing policies, Preparation of national plans for water resources protection and conservation;

Control of municipal water withdrawals, by reducing physical water losses in drinking and industry water supply networks, mainly in urban areas. Foreseen activities include supply side measures (reparation of water leaks and network upgrade), as well as demand side measures (increased water metering, development and promotion of new water supply codes, etc.).

Control of urban wastewater discharges: Inappropriate wastewater management. i.e. wastewater discharge, is certainly one of the most important sources of pollution. Based on the analysis of wastewater converges, currently the ratio of households connected to public wastewater collection system equals 57.3%; the remaining 46.7% are assumed to use septic tanks for discharge of wastewater. Of these sewage captured water, about 79% are purified-treated, while the remaining captured and not captured sewage waters end up in surface water courses and underground waters. Additional important aspect related to WWM is the presence of a large number of tourists, which creates significant imbalances of pollutant load to water bodies.

Control of irrigation water withdrawals, Irrigation is the one of the largest water consumer. On the other hand current irrigation practices are extremely inefficient. Therefore, a specific focus should be given on upgrading of existing irrigation schemes, to enable use of modern irrigation techniques

Urban planning - Protected areas measures, focused mainly on restoration and improved management of protected areas (e.g. drinking water supply sources)

Urban planning - Other anthropogenic pressure management measures, focused on activities for mitigation of the remaining major anthropogenic pressure

4.2.3. Flood risk vulnerability under climate change

It is widely accepted that heavy precipitation events will become more frequent and/or intense under global warming (Allen and Ingram, 2002; Hegerl et al., 2007). An increase in rainfall intensity may occur even in areas that are getting drier on average (Christensen and Christensen, 2004).

Preliminary assessments of potential future risk indicate that flood risk will increase substantially in terms of the frequency of extreme events and the degree of risk nationally. As a result of the increases in the frequency of heavy rainfall predicted by climate models, it is likely that flood risk will increase over large parts of Europe (Norwegian Meteorological Institute, 2013). The future magnitude and frequencies of floods are not clear, in part due to the uncertainty about the future evolution of the underlying causes but also because of other factors, including the effects of human intervention.

Uncertainties arise in part from an incomplete knowledge of external factors affecting the climate system, such as future greenhouse gas emissions or land use change. Model uncertainty is another source. Climate change models may yield different responses as a result of differences in physical and numerical formulations. Downscaling of global models to smaller geographical scales can also increase uncertainty.

Extreme rainfall episodes generally lead to significant floods. Individual daily rainfall is often linked to flash floods of limited spatial extent, but multi-day rainfall generally has a broader spatial footprint and, thus, more extensive flooding can be explained. High-intensity rainfall, among other things, can cause flooding, landslides, landslides, spills of streams and drainage channels, impeded traffic flow, decrease in water quality, pollution of groundwater released, and a reduction of arable land.

In the Water Management Strategy in Montenegro (2017-2035), statistical analysis of the maximum 24 hour rainfall was performed for 22 stations for different time periods until 1996.

Additionally, statistical analysis of maximal annual 24h precipitation data is applied to fit the selected theoretical distribution to the period from 2008 to the present. The annual maximum daily rainfall from the observed record was fitted with the Gumbel and Ln-Normal probability distribution for all 20 stations.

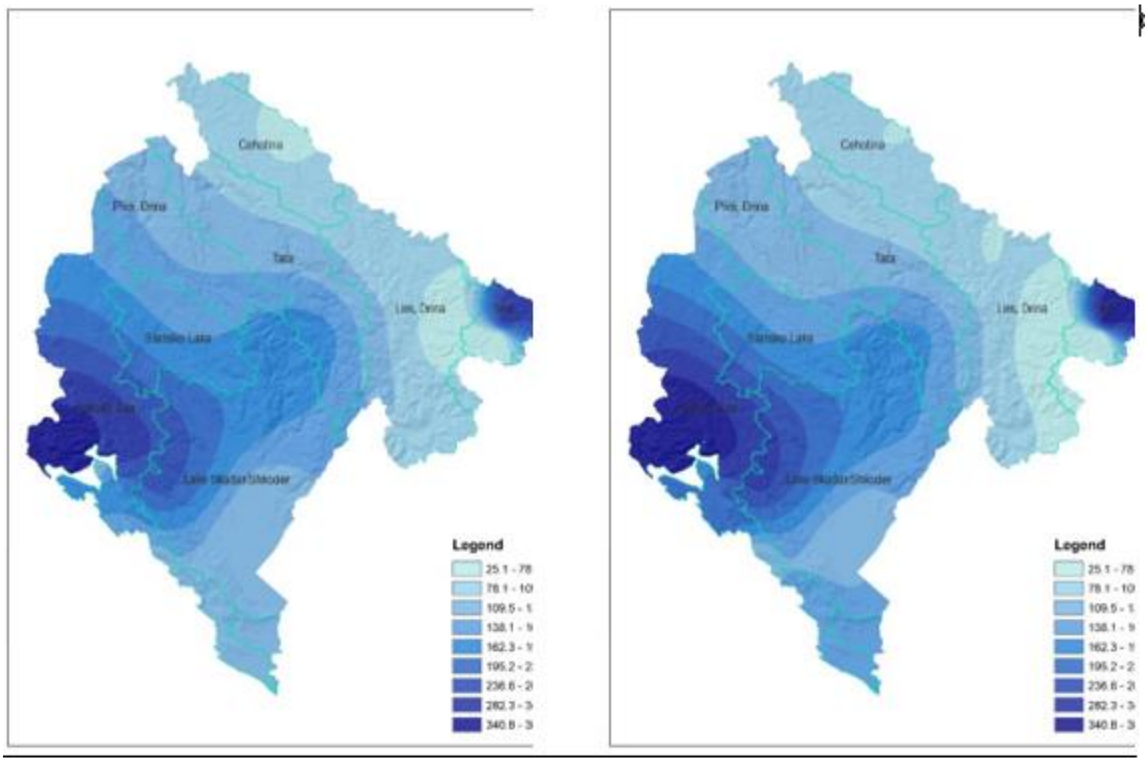
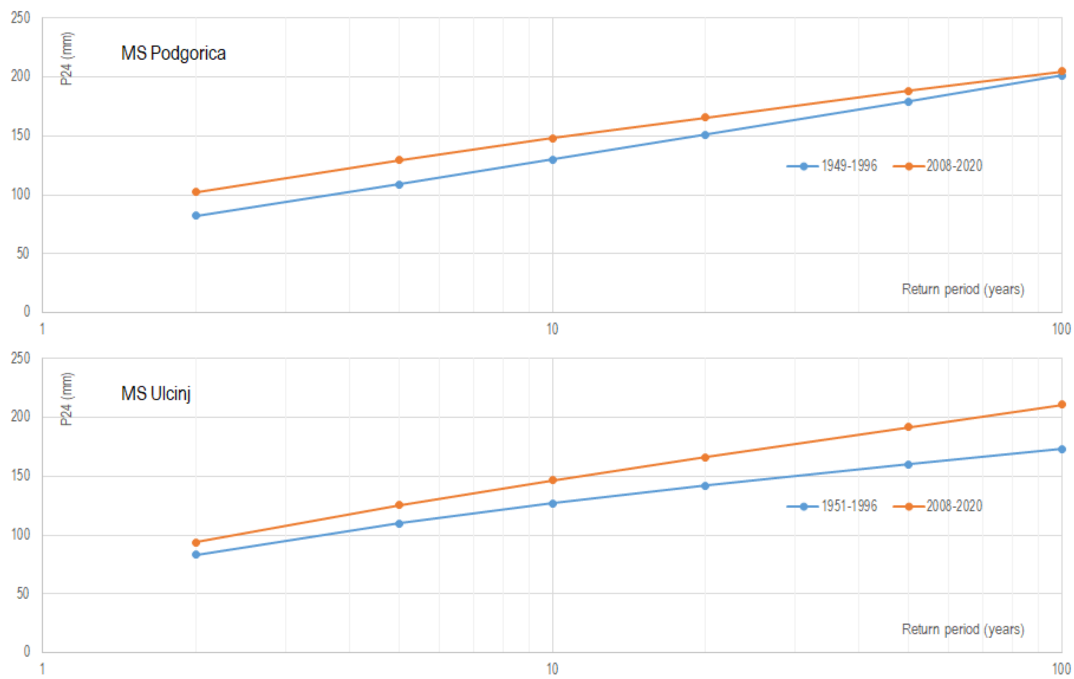


Figure 25 Max 24-hour precipitations with 10 years return period (up to 1996, 2008-2020)

A significant positive change exists in the daily maximal precipitations in the northern region (Cehotina and Ibar) and in the whole coastal region. Also positive change exists in the Skadar lake watershed. In the regions of Piva, Tara and Lim sub-basins, there are a slight decrease or minimal change in the extreme precipitation. Figure below shows the daily precipitation maxima for two considered time periods in Podgorica, Ulcinj and Barane.



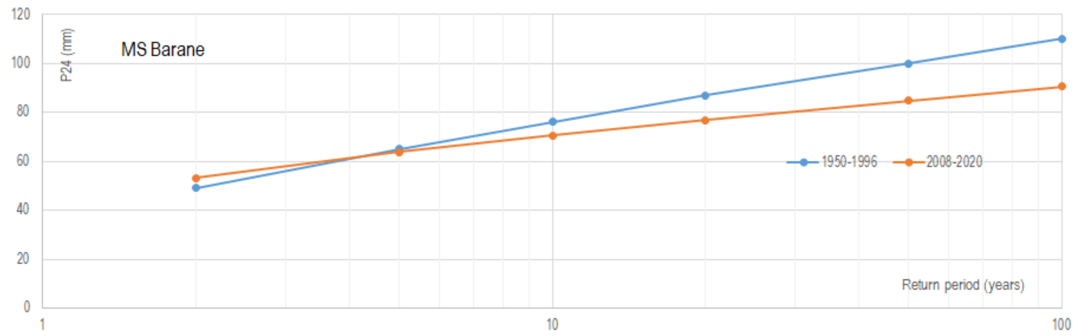


Figure 26 Daily precipitation maxima with different probability of occurrence, for two considered time periods in Podgorica, Ulcinj and Berane

4.2.4. Susceptibility assessment of torrential floods

Torrential, or flash floods can be one of the most devastating natural hazards, causing significant economic damages throughout the World annually, as well as a danger to human life. As torrential floods occur in relatively remote mountainous areas, where human communities are generally sparser, the danger of torrential floods is not as understood and documented as it should be.

Montenegro, is a country of primarily mountainous nature, rich with freshwater. Natural factors such as steep slopes and peculiar geology, coupled with human factors such as inadequate natural resources management including deforestation and increased agricultural activity, contribute to an increased susceptibility to torrential floods.

Numerous studies suggest that most of Montenegro's rivers, both coastal and inland, in the upstream part of the basins are susceptible to torrential floods. In the National Plan for Flood Protection[25] proposed by the Government of Montenegro, an inventory of 300 torrential basins is mentioned, and solely an inventory of torrents with the potential to damage primary transport infrastructure is reported. As torrential floods have a much larger damage potential that the transport infrastructure, the need to more thoroughly identify areas susceptible to torrential floods is evident.

Methodology & Data

The GIS Matrix Method (GMM) was used to develop a Torrential Flood Susceptibility Model (TFSM) in the Vrbas River Basin in Bosnia and Herzegovina[26] and has since been used regionally for other river basins, providing valuable information with relatively attainable input data. The GMM is a quantitative method which uses a statistical analysis to establish the susceptibility model index to torrential flooding in an observed area. Although this model cannot define susceptibility in absolute terms, it can recognize a potential relative susceptibility, which is calculated for the entire observed surface using a series of measurable relevant factors of the phenomenon of torrential floods.[27]

The model is completely developed in a GIS environment, on the basis of six input layers of factors well known to impact the occurrence of flash floods, and a flash flood inventory, to be used for validation. The six factors selected for the preparation of the TFSM are:

[25] https://www.gov.me/dokumenta/b5dc6d8c-90d2-491d-a51a-fd62cd627d3a

[26] https://www.researchgate.net/publication/322662241_Assessment_of_torrential_flood_susceptibility_using_gis_matrix_method_Case_study_-_Vrbas_river_basin_B_H

[27] https://www.researchgate.net/publication/322662241_Assessment_of_torrential_flood_susceptibility_using_gis_matrix_method_Case_study_-_Vrbas_river_basin_B_H

- Slope
- Forest density
- Curve number
- Drainage network density
- Land use – land cover
- Erosion category

Slope: created in a GIS environment on the basis of the EU-DEM[28] with a spatial resolution of 25m. The degree of slope raster layer was subsequently reclassified into five classes: (1) 0–5°, (2) 5–15°, (3) 15–25°, (4) 25–35°, (5) >35°. Slope angle influences the timing of runoff and the infiltration process. Steeper slopes and steeper drainage channels contribute to quicker flow response and a higher peak flow. As the GMM asks for vector format layers, the reclassified raster layer was converted to polygon.

Forest density: obtained as a raster layer from the Copernicus Land Monitoring Service[29] and reclassified into five classes: (1) 0%, (2) 1–25%, (3) 25–50%, (4) 50–75%, (5) 75–100%. A higher forest density decreases torrential flood potential as it retains more water. The reclassified raster layer was again converted to polygon.

Curve number: created in a GIS environment on the basis of a polygon soil map[30] and a polygon land use map[31]. The CN represents the run-off and infiltration to subsoil characteristics of a study area. The Curve Number (CN) was reclassified into four classes: (1) 33–49, (2) 50–77, (3) 78–89, (4) 90–100, where higher CN represents lower infiltration and higher run-off, thus increasing torrential flood susceptibility.

Drainage network density: created in a GIS environment based on vector layers of river basins (up to 10 km^2) and river networks, both developed using Arc Hydro tools, resulting in a polygon layer with drainage network density (km/km^2), subsequently reclassified into five classes: (1) 0–1 km/km^2, (2) 1–2 km/km^2, (3) 2–3 km/km^2, (4) 3–4 km/km^2, (5) 4-18 km/km^2, where higher values result in higher torrential flood susceptibility. As it incorporates the hydrological conditions into the TFSM, it is one of the most important characteristics for evaluating potential run-off.

Land use: obtained from the Corine Land Monitoring Service, which was used for the preparation of the drainage network density layer as well. Land use is another factor that influences run-off and infiltration, as natural vegetative areas allow for more infiltration, contributing to a lower flash flood susceptibility; and impermeable, urban areas limit infiltration and increase run-off, thus contributing to a higher flash flood susceptibility. The Corine land cover layer was reclassified into 5 classes based on the CLC codes as follows: (1) 111, 112, 121, 122, 123, 124, 311, 312, 313; (2) 141, 142, 231, 243, 321, 322, 323, 324; (3) 132, 133, 211, 221, 222, 223, 241, 242; (4) 131, 331, 332, 333, 334; (5) 335, 411, 421, 422, 511, 512, 522, 523.

Erosion category: a Soil Erosion Map developed using the EPM[32] was obtained and digitalized in a GIS environment to obtain a vector layer. As torrential floods and soil erosion processes are known to

[28] https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-eu-dem
[29] https://land.copernicus.eu/pan-european/high-resolution-layers/forests/tree-cover-density/status-maps/tree-cover-density-2018
[30] https://esdac.jrc.ec.europa.eu/content/european-soil-database-v20-vector-and-attribute-data

[31] https://land.copernicus.eu/pan-european/corine-land-cover/clc2018
[32] Erosion Potential Method

occur hand in hand, it is safe to assume that areas with elevated danger of erosion are likewise likely to have a higher torrential flood susceptibility. The erosion map, according to the EPM methodology is already classified into five categories: (1) Excessive erosion (2) Strong erosion (3) Medium erosion (4) Low erosion (5) Very low erosion; and was used as such.

The factors influencing the TFSM are reported in the figure bellow.

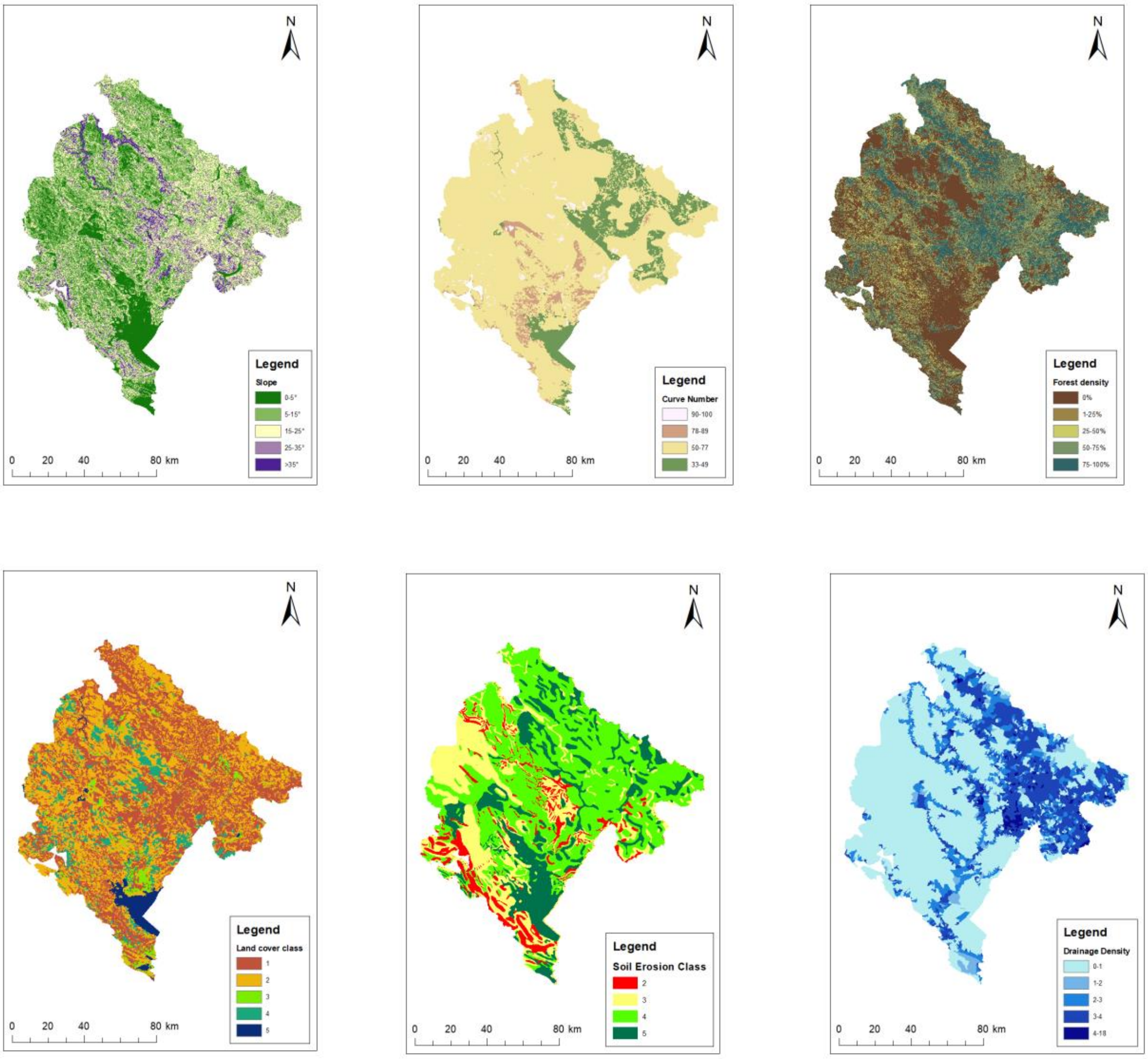


Figure 27. Factors influencing the TFSM in the study area

The first step of developing the GMM is the creation of the **Total Surface of the Study Area Matrix (TSSASM)**, which is developed in a GIS environment by intersecting all six previously prepared vector layers and combining the classes of each polygon into a unique combination of codes, for the whole study area, i.e. Montenegro.

The second step is the formation of the Torrential Basin Matrix (TBM), which is simply the TSSASM, clipped to the extent of torrential basins known to flood according to the torrential floods inventory. The inventory was generated in a GIS environment according to information from the previously

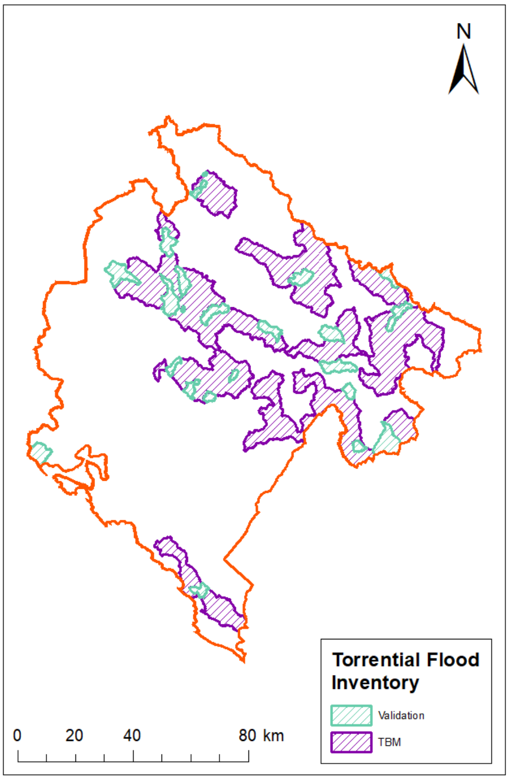


Figure 29. Torrential flood basins inventory

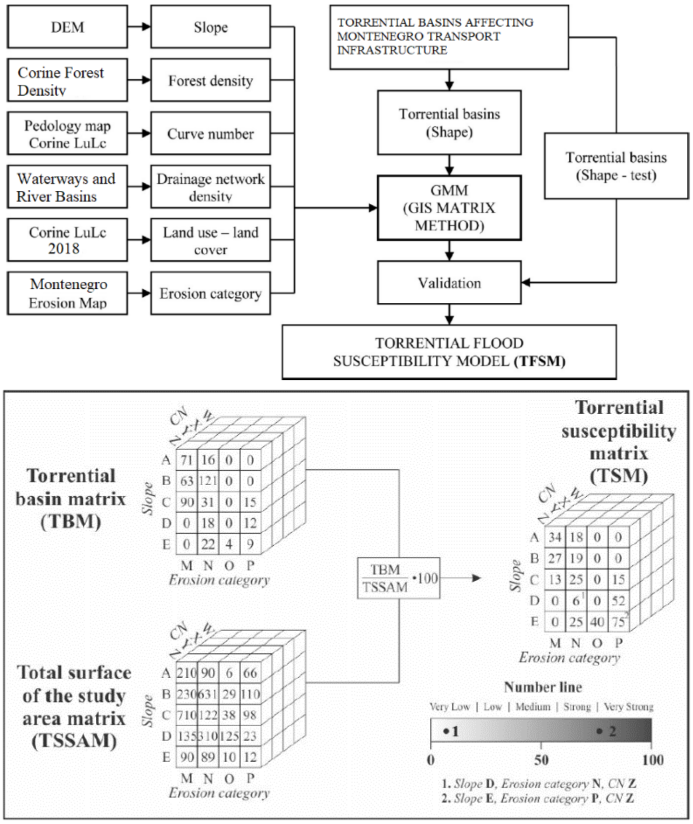


Figure 28. Torrential Flood Susceptibility Model based on GMM[2]

mentioned National Plan for Flood Protection33. Out of the 4,008 km2 of identified basins susceptible to torrential flooding, 85%, spread evenly throughout the study area were used for the TBM, while the rest were left for the validation process. The torrential flood basins inventory is shown in Figure 29.The Torrential Susceptibility Matrix (TSM), which is the final product of the TFSM is generated by dividing the areas of each combination of factor classes that fall into the TBM and the areas that fall into the TSSASM, and multiplied by 100. In other words, the TSM represents the percentage of each combination of impacting factors that fall into the identified torrential flood basins, with values between 0-100%. The result is a vector layer of polygons with the percentage of source area in each combination of influencing factors in relation to the entire study area. The TSM is reclassified (natural breaks method) and shown visually in 5 classes in Figure 30.

The TFSM is validated with the "degree of fit" method, calculated as:

$$DF_i = \frac{m_i}{t_i} \Big/ \sum \frac{m_i}{t_i};$$

where m_i is the area occupied by the source area of the torrential basin at each susceptibility level as previously classified and t_i is the total area covered by the susceptibility level.

The degree of fit for each susceptibility level represents the percentage of mobilized area assigned to each susceptibility class. The degree of fit was calculated for only the torrential flood basins in the

[33] https://www.gov.me/dokumenta/b5dc6d8c-90d2-491d-a51a-fd62cd627d3a

TSM as well as for all torrential flood basins including the ones left for validation. The results are presented in **Error! Reference source not found.**.

Results Interpretation

According to the TSM map showing the relative torrential flood susceptibility in 5 classes, the north and north-eastern part of Montenegro is the most susceptible to torrential flooding, along with the coastal region. This is expected, as most of the identified torrential flood areas from the inventory are in those regions. However, areas with medium to low susceptibility should not be ignored, as many studies so far report generally strong susceptibility to torrential flooding. Nevertheless, the map allows for identification of areas more or less susceptible to torrential flooding in relative terms. In situations where excess rainfall is expected or observed in a certain area, by referring to the torrential

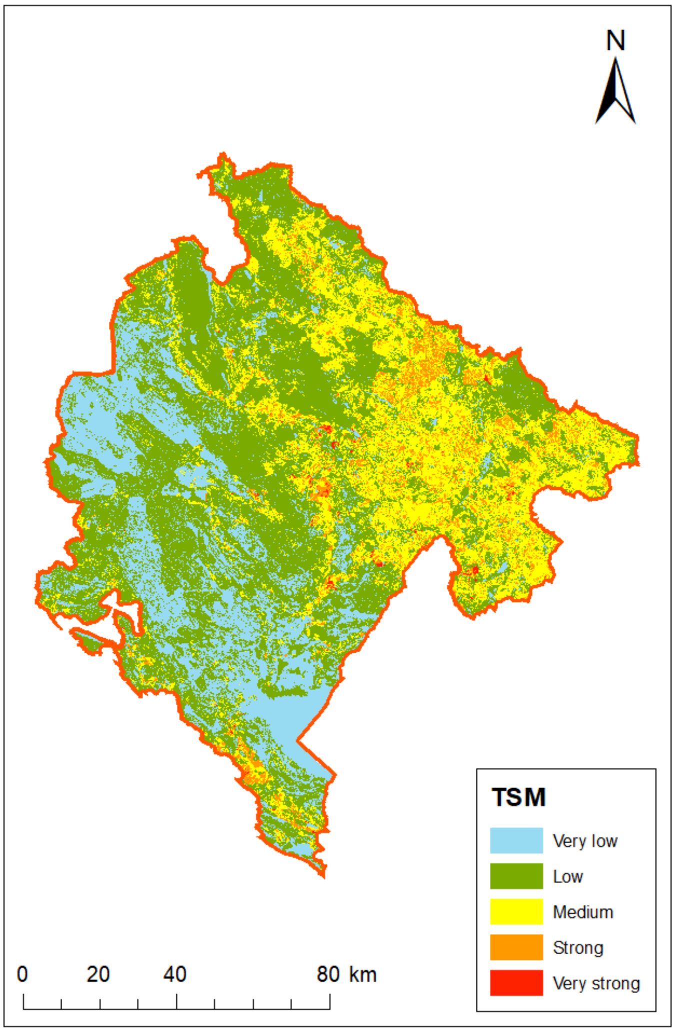


Figure 30. Torrential Susceptibility Matrix

susceptibility map, the relevant institutions can focus on areas more prone to torrential flooding.

The definitive goal of the degree of fit as shown below was to evaluate the quality of the produced susceptibility model, as a predictive resource used to explain the spatial distribution (location) of torrential basins in the project area. The lower the degree of fit in the low and very low susceptibility classes (relative error), and the higher the degree of fit in the high or very high susceptibility classes (relative accuracy), the higher the quality of the susceptibility map[34]. According to the validation process, 67-69% of the area falls into the "strong" and "very strong" susceptibility classes and only 3% fall into the "very low" susceptibility class, alluding to satisfying results.

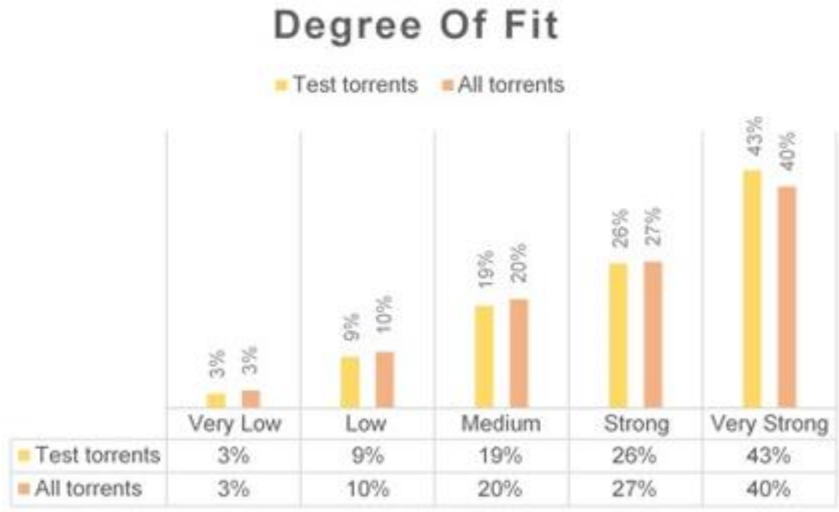


Figure 31 Degree of fit

Conclusion

The TFSM based on GMM has proven as a relatively useful tool for identifying relative torrential flood susceptibility, performing well in the Montenegro study area, and providing valuable information to be used in crisis management. The main limitation of the Montenegro TFSM is the lack of proper inventory of torrential floods to be used for the development of the model, as all of the torrents identified to affect the transport infrastructure are located in the north and to a much smaller extent in the coastal zone. However, if an inventory is made available with areas other than the transport infrastructure, the model can be further improved.

4.3. Climate-driven vulnerabilities and gender-disaggregated impacts of the water sector

Men and women manage, use and benefit from water for different purposes due to the gender-based roles in the family and society.

Monitoring data for Montenegro for the SDG 6 are indicating that in 2020, 85% of the population uses a **safely managed drinking water services**, 45% of the population uses a **safely managed sanitation services**, 99% has a handwashing facility with soap and water available at home, 45% of domestic water in Montenegro is safely treated, 88% of monitored water bodies has good ambient water quality[35].

[34] Collapse dolines susceptibility mapping in Doukkala Abda ...https://link.springer.com/article/10.1007/s40808-015-0064-8

[35] UN water: SDG 6 snapshot in Montenegro, available at: https://www.sdg6data.org/country-or-area/Montenegro, last seen 20.03.2022

The IPCC, 2014: Climate Change 2014: Synthesis Report sets a “high confidence on Reduced access to water for rural and urban poor people due to water scarcity and increasing competition for water”, with gender as a risk (among others), in the adaptation issues and prospects”.

Namely, due to the female overrepresentation in the unpaid family labor, women are the primary users and managers of water for the cooking, cleaning, care for children and elderly, sanitation, and health.

In **agriculture,** women are also more represented in the family unpaid labor and are mostly involved in the irrigation activities related to the cultivation of crops – mostly near the home, and nurturing livestock for their own and small-scale commercial needs.

On the other hand, men are more involved in large-scale farming and agriculture or livestock.[36]

Still, the lower female representation as owners in the agricultural sector (13% of women are holders of individual agricultural holding and 6% are managers of business entities in Montenegro[37]) are disabling them from engagement in the decision-making activities regarding the water needs for irrigation and home use (clean water).

As noted in the health sector: **droughts** as one of the climate change consequences are strongly affecting both men`s and women`s mental health (in agricultural areas), also additionally burdens the unpaid labour of women in the households due to the water insufficiency. Data from the agricultural sector are indicating that men can be more affected by droughts due to the fact that in 87% they are holders of individual agricultural holdings, in 60% are agricultural workers, in 94% are managers of business entities. Still, the fact is that 65% of women who are unpaid family workers have to be also evidenced in the gender differences of the burden of labour in the cases of droughts.

The national data and figures which has been discussed above bring to a conclusion that additional efforts are needed in order to provide the total population with safely managed drinking water, safely managed sanitation services, and safe water treatment due to the fact that these activities are related to the women`s burden in the family labor.

Table 12 Access of the households to water services

	Households	**First income quintile**	**Roma**	**Rural**
Basic water services	99.1%	98.8%	98.4%	98%
Improved water services	99.5%	99%	98.9%	98.6%
Accessing water in sufficient quantities	85%	78.2%	81.9%	82%

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36 Women`s Environment & Development Organization: “Gender, climate change and water connections”, available at: https://unfccc.int/files/adaptation/knowledge_resources/databases/partners_action_pledges/application/pdf/wedo_furtherinfo_water_190411.pdf

37 Agricultural census 2010

The following data are defining the vulnerable groups in terms of gender and the aces to water on the household level:

- Multiple indicators cluster survey in 2019 (MONSTAT)[38] provides data on the access of the households to basic water services[39], improved water services[40], and the access to water in sufficient quantities for the total national households, first income quintile (the poorest population[41]), Roma and Rural households. According to the data, the most vulnerable in terms of basic water services are the rural households (98%) as well as for improved water services (98.6%), while the access to water in sufficient quantities is lowest among the poorest (first income quintile) in 78.2%, followed by Roma and Rural households.
- Multiple Indicator Cluster Survey 2018[42] defines a Housing deprivation rate as a Percentage of household members living in households deprived of any one of four housing deprivation items: are: i) leaking roof, damp walls, floors or foundation, or rot in window frames or floor, ii) lack of bath or shower in the dwelling, iii) lack of indoor flushing toilet for the sole use of the household and iv) problems with the dwelling: too dark, not enough light.

Once again, Roma and rural population are the most vulnerable groups when it comes to the access to water and improved waters services, as well as water in sufficient quantities for the household purposes.

And again we have to go back to data from the Gender Equality Index in Montenegro on the time-domain, stating that the percentage of women cooking and/or doing housework, every day (18+ population) is in 68% and male`s share is 10.3 In addition to that in the category of caring for and educating their children or grandchildren, elderly or people with disabilities, every day (%, 18+ population) the share of women is 42.7% whilst male share is 23.8%, we can conclude that women who are carrying the heaviest burden of the unpaid family labor should be defined as vulnerable in the access to water for household use.

In purpose of identifying and defining the gender based vulnerable groups in 4 listed sectors in Montenegro a Multifactor analysis approach is needed due to the complexity and different nature of the factors which are defining the gender-based vulnerability (social, economic, climate, cultural).

As shown in the section **Gender profile in Montenegro in the context of water, tourism, agriculture and health** there are significant differences between women and men that have to be considered in order to clearly and precisely define the gender-based vulnerabilities in each of the sectors.

[38] The Montenegro Multiple Indicator Cluster Survey (MICS) and the Montenegro Roma Settlements MICS were carried out in 2018 by the Statistical Office of Montenegro (MONSTAT) as part of the Global MICS Programme.

[39] Percentage of household members using improved sources of drinking water either in their dwelling/yard/plot or within 30 minutes round trip collection time

[40]Percentage of household members using improved sources of drinking water ESPN: "Access to essential services for low-income people Montenegro", Jadranka Kaluđerović and Miloš Đurović, 2020: Improved sources of drinking water are those using any of the following types of supply: piped water (into the dwelling, compound, yard or plot, to the neighbour, public tap/standpipe), tube well/borehole, protected dug well, protected spring, rainwater collection, and packaged or delivered water.

[41] EUROSTAT: The first quintile group represents 20 % of the population with the lowest income (an income smaller or equal to the first cut-off value), and the fifth quintile group represents the 20 % of population with the highest income (an income greater than the fourth cut-off value).

[42] Multiple Indicator Cluster Survey 2018, Montenegro and Montenegro Roma Settlements, available at https://www.unicef.org/montenegro/media/15976/file/mne-media-publication1002.pdf

In other words, gendered vulnerabilities are resulting from multiple interactions of social (in wide meaning of the term) and biophysical factors. In that regard following aspects have to be cross-referenced in defining the gendered vulnerability:

1. Geographical (Central, Coastal and North if applicable, which means if regional data are available and if the vulnerability has regional characteristics)
2. Governance and institutional factor (adaptation measures with gender responsive dimension)
3. Household level (power relations, gender-based roles, control over resources, ownership)
4. Coping and adaptive capacity[43] (socio-economic factors, decision making processes)

The level of vulnerability is measured by the following scale: Low, Moderate, High, Not known since there are no sufficient sex-disaggregated data on one hand, and due to the fact that the nature of the indicators is different. Therefore, the cross-reference and measurement has been done upon above listed measurement scale in a form of a qualitative analysis.

Column "Sectoral vulnerability" lists the key identified sectoral adaptation vulnerabilities correlated with the "human" factor, meaning directly or indirectly endangering socio-economic, health, quality of living aspects.

The subjectivity of this Multi criteria analysis should be once again validated with the national stakeholders and relevant institutions.

Table 13 Table Gender based multi criteria analysis

[43] Available data will be used as a criterion in the "General gender statistics" section

Sectoral vulnerability	Geographical area (where applicable)			Household level Gender-based roles	Gender differences in exposure and hazards	Gender differences in the Coping and adaptive capacity	GENDER DISAGGREGATED IMPACTS[44]
	North	**Costal**	**Central**				
Water	Single choice: Low Moderate High Not known	Single choice: Low Moderate High Not known	Single choice: Low Moderate High Not known	Single choice: Low Moderate High Not known	Single choice: Low Moderate High Not known	Single choice: Low Moderate High Not known	**Health:** Water-borne diseases related to the time domain indicator indicates women as a vulnerable group due to the share of women doing housework, every day (18+ population) is in 68% and male`s share is 10.3% in Montenegro. **Agriculture:** Men can be more affected by water-related risks due to the fact that in 87% they are holders of individual agricultural holdings, in 60% are agricultural workers, in 94% are managers of business entities. Still, the fact is that 65% of women who are unpaid family workers have to be also evidenced in the gender differences of the burden of labor in the cases of floods/droughts as well as water borne diseases. **Roma and rural population** are the most vulnerable groups when it comes to the access to water and improved waters services, as well as water in sufficient quantities for the household purposes
Water scarcity due to reduction of water availability and increased demand, above all in summer periods	High	High	High	Moderate High	Moderate High	Moderate High	Roma and rural population are the most vulnerable groups when it comes to the access to water and improved waters services, as well as water in sufficient quantities for the household purposes. Health: Water-borne diseases related to the time domain of women doing housework, every day (18+ population) is in 68% and male`s share is 10.3% in Montenegro. In addition to that in the category of caring for and educating their children or grandchildren, elderly or people with disabilities, every day (%, 18+ population) the share of women is 42.7% whilst male

[44] The Multi Criteria Analisis is populated by the RVA and was based on expert judgment, literature review, and exchange with the relevant stakeholders

							share is 23.8%, we can conclude that women who are carrying the heaviest burden of the unpaid family labor should be defined as vulnerable in the access to water for household use. Agriculture: Men can be more affected by water-scarcity due to the fact that in 87% they are holders of individual agricultural holdings, in 60% are agricultural workers, in 94% are managers of business entities. Still, the fact is that 65% of women who are unpaid family workers have to be also evidenced in the gender differences of the burden of labor in the cases of floods/droughts as well as water borne diseases
Reduced water quality at the point of abstraction	Moderate	High	High	Moderate High	Moderate High	Moderate High	Roma and rural population are the most vulnerable groups when it comes to the access to water and improved waters services, as well as water in sufficient quantities for the household purposes. Health: Water-borne diseases related to the time domain indicator indicates women as a vulnerable group due to the share of women doing housework, every day (18+ population) is in 68% and male`s share is 10.3% in Montenegro. In addition to that in the category of caring for and educating their children or grandchildren, elderly or people with disabilities, every day (%, 18+ population) the share of women is 42.7% whilst male share is 23.8%, we can conclude that women who are carrying the heaviest burden of the unpaid family labor should be defined as vulnerable in the access to water for household use.
Increased flood risk (fluvial and meteorological floods)	Moderate to High	Moderate to High	High	Moderate High	Moderate High	Moderate High	Health: Water-borne diseases related to the time domain indicator indicates women as a vulnerable group due to the share of women doing housework, every

							day (18+ population) is in 68% and male`s share is 10.3% in Montenegro. Agriculture: Men can be more affected by floods due to the fact that in 87% they are holders of individual agricultural holdings, in 60% are agricultural workers, in 94% are managers of business entities. Still, the fact is that 65% of women who are unpaid family workers have to be also evidenced in the gender differences of the burden of labor in the cases of floods as well as water borne diseases.
Economic damage due to reduced inflow of water to the economy and the population	Hight	Hight	Hight	Not known	Not known	Not known	No sex-disaggregated data on economic damage are available.
Economic damage to flora and fauna in the aquatic ecosystem due to reduced inflows and changes in water temperatures	Low	Low	Low	Not known	Not known	Not known	No sex-disaggregated data on economic damage are available.

5. Economic impact assessment of the climate change impact on the water sector

5.1. Examination of the critical role of water resources for the national economy, sustainability and security - Montenegro Virtual Water Trade

About the Water Footprint & Virtual Water Trade

Water Footprint (WF) is a concept that is used to establish a better understanding of the critical role of water resources for a country's economy, sustainability and security. It is defined as the total volume of water used for production of the goods and services consumed by an individual, community or business, however covering the whole process from manufacturing raw materials to direct operations, and consumer use of a product. Accordingly, the concept includes not only direct water use, but also indirect water use generated by the production process. Therefore, by analyzing the water footprint of a country (or region within the country) decision makers can follow the path of water through economic activity, with a basis of knowledge that can be used to inform their decisions on allocation, trade, comparative advantages, and ecosystem support.

Water footprint can be calculated for any defined group of consumers (e.g. individuals, family, settlement, province, basin, country, etc.) or producers. It is geographically explicit factor showing both volume of water use and locations, and it is directly related to consumption patterns of the people concerned.

On the other hand, the water that is used in the production process of an agricultural or industrial product measured over its full supply chain is called the 'virtual water' (VW) contained in the product. The VW concept, in general, aims at measuring how water is embedded in the production and trade of food and other consumption products. For example, for producing a kilogram of grain grown under rain-fed and favorable climatic conditions, 1 to 2 m^3 of water is needed. For the same amount of grain but growing in an arid country, where the climatic conditions are not favorable (high temperature, high evapotranspiration) up to 3 to 5 m^3 of water is needed.

Thus, if a country exports a water-intensive product to another country, it exports water in virtual form. In this way some countries support other countries in their water needs. For water-scarce countries it could be attractive to achieve water security by importing water-intensive products instead of producing all water-demanding products domestically[45]. Reversibly, water-rich countries could profit from their abundance of water resources by producing water-intensive products for export [46].[47] Similarly, if a variety of water-intensive products are produced in one region (e.g. a river basin) and used in other regions, regardless whether in the same country or exported, the volume of WF contained in these products is relocated from that region.

Therefore, the total water used within a country or a region itself is not the right measure of the population's actual appropriation of freshwater resources. In the case of net 'import' (or input) of VW into a country or region, the VW volume should be added to the total domestic water use in order to

[45] virtual water trade - Slidesharevirtual water trade – SlideShare https://de.slideshare.net/NagarajS1/virtual-water-trade/2

[46] Virtual water (C8.04) – GWP thishttps://www.gwp.org/en/learn/iwrm-toolbox/Management-Instruments/Promoting_Social_Change/Virtual_water

get a picture of a population's real use of water resources. Similarly, in the case of net 'export' of virtual water from a country or a region, this virtual water volume should be subtracted from the volume of domestic water used. The sum of domestic water use and net virtual water import then make the water footprint of a country or a region.

Following, an attempt is made for calculating the WF of Montenegro. The objective of the analysis is valuation of the in-country water use, while only the "blue Water Footprint" component is taken into consideration[48].

The analysis includes three sectors for which water use is calculated: residential, industry and agriculture. However, while water used in the residential sector comes 100% from 'national waters', industrial and agricultural goods can either be produced locally or imported. Furthermore, part of the industrial and agricultural goods produced locally are exported. Hence, the local production of industrial and agricultural goods is calculated according to local water use data. The VW import is calculated, when applicable, by applying local water use standards. This is with the purpose of appropriating the amount of water that Montenegro would be using if all of its consumed products were to be produced locally. Nevertheless, as it is not always the case that the imported products can be produced locally, or local data on water use for those particular products is scarce, in such cases WF-data from neighboring countries is used. If this is not possible, then global average water footprint data are used.

National Residential and Industrial Water Use

Water supply services in Montenegro are provided by public entities. Of these there are 22 municipal water supply and sewage enterprises (Vodovod i Kanalizacija, ViK). All ViK's publish annual technical/non-financial and financial data on their performance, from which are derived water quantities provided to both households/residential sector and to industrial facilities. The water use for these two sectors, as well as the non-revenue water, are derived for each ViK and summed on a national level. For the population that is not covered by the public water supply system, the water use was estimated according to the regional averages as calculated for the covered population. The findings are presented in the **Error! Reference source not found.** chapter.

National Agricultural Water Use

The agricultural sector in general is not amongst the key sectors of the country, especially considering water use. Solely around 2,000 ha of land is irrigated[49] and negligible 7.3 million m^3 of water is used for irrigation[50].

Imported and Exported Virtual Water

Imported and Exported Industrial Virtual Water

The virtual water incorporated in industrial products that is internationally traded by Montenegro is estimated based on national industrial water use averages, and economic trade data.

Industrial water footprint of countries worldwide is reported on the water footprint network website[51], however, these are for the period 1996-2005, when Montenegro was a part of firstly SR

Yugoslavia, then Serbia and Montenegro, thus raising questions regarding the data's quality both in terms of being outdated as well as the distortion due to political changes. This raised the need for re-assessing the blue water footprint of the industrial sector in Montenegro, which was done following the equation:

$WF_{blue,ind}$ (m^3/€) = $WU_{nat,ind}$ (m^3/year) ÷ GVA_{ind} (€/year)

Where:

$WF_{blue,ind}$ – blue water footprint of industrial products

$WU_{nat,ind}$ – national water use in the industrial sector

GVA_{ind} – Gross Value Added of industrial products

The GVA_{ind} was derived from the database of the Statistical Office of Montenegro[52], amounting to 238.2 million € in 2020, the year for which the $WU_{nat,ind}$ was estimated at 28.5 million m^3 of water[53]. This resulted in a $WF_{blue,ind}$ of 121 m^3/1000 €, which is comparable to the Serbia and Montenegro average of 124 m^3/1000 US $.

Once the $WF_{blue,ind}$ was estimated, the net virtual trade was calculated following the equation:

$VW_{net\ traded,ind}$ (m^3/year) = $Trade_{net,ind}$ (€/year) × $WF_{blue,ind}$ (m^3/year)

Where:

$VW_{net\ traded,ind}$ – net virtual traded water

$Trade_{net,ind}$ – net trade of industrial products

The $Trade_{net,ind}$ was also derived from the database of the Statistical Office of Montenegro, amounting to 1.34 billion € in 2020, resulting in a $VW_{net\ traded,ind}$ of 163 million m^3.

Imported and Exported Agricultural Virtual Water

The internationally traded virtual water incorporated in agricultural products is similarly estimated based on national water footprint of various food products, economic trade data and average food prices.

The water footprints (m^3/ton) of crops and derived crop products as well as farm animals and animal products are also reported on the water footprint network website on national and subnational levels, and were taken as such for Montenegro. In order to transform the water footprints from m^3/ton to m^3/euro, average prices for the internationally traded goods were procured[54]. The complete equation according to which the virtually traded water in food products was calculated is:

$$VW_{net\ traded,prod}\ (m^3/year) = Trade_{net,prod}\ (€/year) \div price_{prod}\ (€/ton) \times WF_{blue,prod}\ (m^3/ton)$$

Where

$VW_{net\ traded,prod}$ – net virtual traded water in crop product

$Trade_{net,prod}$ – net trade of crop product

$price_{prod}$ – average price of crop product

$WF_{blue,prod}$ – blue water footprint of crop product

The $Trade_{net,prod}$ was derived again from the database of the Statistical Office of Montenegro, and is summed in **Error! Reference source not found.**.

The average price of all traded products was estimated at 0.004 euro/ton, while the average $WF_{blue,prod}$ of all traded products was estimated at 113 m^3/ton.

The sum of $VW_{net\ traded,prod}$ of all crop products returns the total virtually traded water incorporated in crop products.

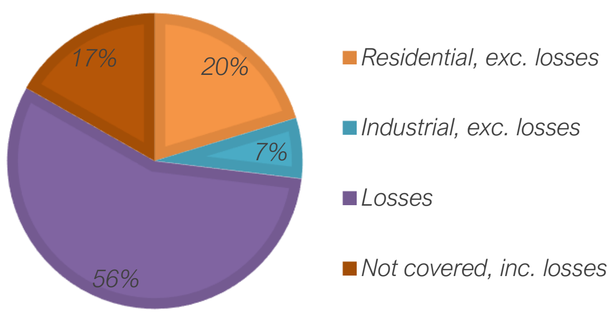
The net virtual trade was calculated for 13 groups of food products separately, which when summed amount to 12.4 million m^3 of water.

Result interpretation and findings

Examining **Error! Reference source not found.**, it is visible that most of the surface water that is used i n Montenegro is part of the municipal water supply systems, where the water delivered to the residential sector amounts for 20% and the industrial sector for 7% of the total water use. On the other hand, around 17% is water used outside of the water supply systems. However, out of the total 152 million m^3 used annually, 56% are losses from the ViKs' water supply network, while the agricultural water use is negligible in comparison.

Table 13. National residential, industrial and agricultural water use (million m^3/year)

National water use	*Mm^3/year*
Covered, inc. losses	***126***
Residential, exc. losses	*31*
Industrial, exc. losses	*10*
Losses	*85*
Not covered, inc. losses	***25***
Total	***152***
Agricultural water use	***7.3***



As far as the international trade is concerned, Montenegro is a clear net importer of water, as hinted even in Error! Reference source not found.**, where trade is represented monetarily, especially t hrough industrial products. The total net import of goods is 1.75 billion euro.**

Table 14. International trade in 2020 (million euro/year)

	M €/year		
	Import	*Export*	*Net*
Food products	*457*	*48*	*409*
Industrial products	*1,607*	*269*	*1,339*
Total	*2,064*	*316*	***1,748***

The trade, transformed into values of estimated virtual water is presented in **Error! Reference source n ot found.**, from which the conclusion of Montenegro being a net importer is confirmed. The industrial trade amounts for a large portion of all virtually traded water (93%). The net import of goods of 1.75 billion euro has translated into 175.4 million m^3 of virtually traded water, averaging a blue water footprint of 100 m^3/1000 euro for all imported goods.

Table 15. Virtual water trade in 2020 (million m^3 of blue water/year)

	Mm^3 blue water/year		
	Import	*Export*	*Net*
Food products	*14.3*	*1.9*	*12.3*
Industrial products	*195.7*	*32.7*	*163.0*
Total	*210.0*	*34.7*	***175.4***

Furthermore, the information that the amount of virtual water (32.7 million m^3) exported through industrial products is higher than the locally used water for industrial purposes (10 million m^3) suggests a re-export of a part of the imported industrial goods, a phenomenon that can be assumed occurs with food products as well.

5.2. Economic vulnerability assessment in Water sector

In Montenegro, as in the region, there is no officially defined methodology on the procedure and manner of determining the damage caused by climate change, as well as the methodology for assessing future harmful economic impacts caused by climate change. The activities so far in assessing these damages are mainly based on the activities of concrete assessment of material damage, due to certain emergency events, which are a consequence of changed climate.

In the sector of **water resources**, negative impacts were analyzed in the context of additional costs for import of electricity, due to reduced electricity production, caused by reduced water potentials as a result of climate change,. To carry out this activity it was necessary to:

- Collect appropriate statistical data on the quantity of electricity production in hydropower plants in the previous period;

- Process and analyse collected data, as a basis for further projections;
- Project the future electricity production in hydropower plants, for the basic scenario - the scenario "without climate change";
- Assess quantitative damage - reduced electricity production, caused by climate change, in accordance with established climate scenarios;
- Analyze the prices of electricity imports in the region and Europe and determine future unit prices, as a basis for damage assessment;
- Based on previously collected and processed data, perform calculation and projection of economic damages caused by climate change in this sector.

Defining the time frame for observation/analysis was the next important step. Climate change is a phenomenon that occurs slowly and not so noticeably, so its consequences, namely negative effects, cannot be adequately assessed for shorter periods of time (e.g. up to 20 years), which is common for different types of economic analysis. For this reason, and based on research and recommendations from numerous documents, especially the document "IPCC Special Report, Emission Scenarios" (Intergovernmental Panel on Climate Change, WMO and UNEP, 2000) it was decided to assess economic damage as a consequence of climate change for:

- The period of the near future, until 2050 (Near Future) and
- The period of the distant future, up to 2100 (Far Future).

In the scope of the further analysis, and due to the impossibility to precisely define at this moment the extent of impact on the climate which will occur in these defined periods, and therefore what negative consequences these changes will cause, it was decided to observe two scenarios - more favorable and less favorable, within each period of time. The number of scenarios can certainly be higher, but it is estimated that for the sake of clarity of the analysis, and also its objective (to determine the preliminary approximate level of considered adverse effects), this number of scenarios is sufficient.

Ideally, further analysis would imply that within each considered sector, adverse effects are quantified by defined categories of analysis, for both time frames and for both climate scenarios. Given that this is very difficult at the moment, since adequate researches are scarce, as well as data in Montenegro on it, the experiences in analysis and research in Europe and the world were considered. Data and assumptions in these sources vary, so only those which served to define the criteria for this analysis are presented below.

Within the document *"The Economic Impact of Climate Change in Montenegro"*(UNDP, 2010), the assessment of economic damage for individual sectors was performed on the basis of the following assumptions:

- For the period up to 2050, 2 scenarios: losses of 3% and 8%;
- For the period up to 2100, 2 scenarios: losses of 8% and 15%

Researches abroad have mainly focused on predicting adverse effects on the total national GDPs as a result of climate change. Thus, for example, in a document prepared by the Swiss Re Institute, *"The Economics of Climate Change: No Action not an Option"* (April 2021) the expected impact on global GDP by 2050 was presented, according to four different scenarios, as compared to the world "without climate change". Those are the following scenarios for Europe:

- Decrease of GDP of 2.8%, if the goals of the Paris Agreement are achieved (increase in temperature well below 2 ° C);
- Decrease of GDP of 7.7%, if further mitigation measures are taken (temperature increase of 2 ° C);
- Decrease of GDP of 8.1%, if some mitigation measures are taken (2.6 ° C increase in temperature);
- Decrease of GDP of 10.5%, if mitigation measures are not taken (temperature increase of 3.2 ° C).

As it can be seen, harmful effects by 2050 are estimated in the range from about 3% to approximately 10% for the period until 2050.

The third document that served as a basis for further analysis is the official document of the International Monetary Fund from 2019, *"Long-Term Macroeconomic Effects of Climate Change: A Cross-Country Analysis"* (International Monetary Fund, 2019). In this document, there is analysis of negative impact of climate change on GDP, by countries, grouped in relation to their geographical location and economic situation. The analysis showed that these damages, for a group of countries including Montenegro, would be the following:

- for the period up to 2050: losses of 2.18% and 3.11%;
- for the period up to 2100: losses of 6.05% and 8.25%

It is obvious that the predicted adverse effects within this document are somewhat lower than in the previous ones, which only confirms the view that their prognosis is not simple and depends on numerous input assumptions. Therefore, in order to cover the broader framework of analysis and future estimates, within this document the analysis was performed for for water sector with the **following scenarios**:

1. Near future, damage level by 2050 5% (Near Future 1, NF1),
2. Near Future, damage level by 2050 10% (Near Future 2, NF2),
3. Far future, damage level by 2100 10% (Far Future 1, FF1),
4. Far Future, damage level by 2100 15% (Far Future 1, FF2).

Projections of individual economic categories are made relying on certain growth rates based ither on historical data, or on the fluctuations of a certain category in the past period, or using official GDP growth rates, or certain sectoral rates or a combination of all mentioned above with appropriate estimates of sectorial experts.

In this particular case, some historical rates are not fully relevant due to the atypical 2020. This also applies to the GDP growth rate, which dropped significantly in 2020. For that reason, it was decided to follow the precautionary principle with moderate growth rates, in relation to the initial state in the water sector with proposed annual increase of 0,5%.

As it can be seen, growth rate in water sector is lower, due to real capacity, which is limitted.

In general, negative effects of climate change on the water sector and watercourses have already been described in more detail in other parts of this document, so it should only be repeted here that they can be very diverse from an economic point of view. The impact of climate change on water resources is very different and affects many sectors of the economy. Changes in the quantity, type and distribution of surface water flows, caused by precipitation and changes in temperature, can lead to a reduction in surface runoff, which can then negatively affect both the amount of water supply and water quality.

Water use is wide and diverse: water for human consumption, water for agriculture, water for industry, technical water for wastewater treatment, water for thermal cooling, water for hydropower production, water for transport and recreation, etc.

Although water use has a significant role in all mentioned areas, the most important economic use of water in Montenegro is for electricity production, so the assessment of the harmful effects of climate change in the water sector would be focused on impacts in this area. In order to do this, it was necessary to collect the most important statistical indicators in the field of electricity generation, analyze them in the process of preparation for appropriate projections, determine future quantities of missing electricity due to reduced water potential caused by climate change and finally analyze electricity import prices, in order to quantify economic damages.

Montenegro's energy sector is characterized by high natural potential (coal, hydro potential, biomass potential, wind and solar potential), which is underused, low energy efficiency, as well as dependence on imports of electricity and fossil fuels. The energy sector is of particular importance for the economic and long-term development of Montenegro, which suffers from the consequences of the payment deficit caused by energy imports.

The electricity sector is one of the most important segments of the energy sector in every country, including Montenegro. The installed capacity of power plants participating in the regulation of the system is 874 MW, of which 649 MW in accumulation hydropower plants and 225 MW in thermal power plants. The range of available active power at the threshold of power plants participating in the regulation of the system, depending on regular annual overhauls or necessary delays due to equipment modernization, ranges from 430 MW (August) to 848 MW (January, February, March and December). The realized energy balances of electricity for the past 6 years (period from 2016 to 2021), are presented, as well as the planned energy balance of electricity for the current 2022. Data for the period 2016-2020 are official data of the Statistical Office - Monstat, while data for 2021, as well as the plan for 2022 were taken from the official Energy Balance of Montenegro for 2022.

Table 16 Energy balance of Montenegro – balance of electricity 2014-2020 (GWh)

Structure	**2016**	**2017**	**2018**	**2019**	**2020**[55]	**2021**	**2022**[56]
Hydropower plants	1807.2	1033.8	2092	1621.1	1447.8	2061.3	1876.6
Thermopower plants	1216.2	1265	1444	1506.4	1615.4	1306	1317
Wind power plants	0	95	141	293.4	320.1	322.5	322.1
Solar power plants	2.2	2.2	2.3	2.3	2.3	2.6	3.4
Total production	**3025.6**	**2396**	**3679.3**	**3423.2**	**3385.6**	**3692.4**	**3519.1**
Import	1209.8	1536.9	780	1195.5	5943	N/A	N/A
Export	905.9	416.7	976	942.9	5864	N/A	N/A
Gross energy supply	303.9	1120.2	-196	252.6	79	-191	52.8
Available electricity	3329.5	3516.2	3483.3	3675.8	3464.6	3501.4	3571.9

[55] Statistical Office, Monstat, Energy, Electricity balance, https://www.monstat.org/cg/page.php?id=40&pageid=40.
[56] Energy balance of Montenegro 2022, https://www.gov.me/dokumenta/5fe82480-023b-431a-b8fb-57d67098aada.

Consumption in energy sector	118	119	133.7	128.7	141	N/A	N/A
Transmission and distribution losses	540.7	512.2	503	492.9	486.9	496,9	494.1
Final energy production	**2670.8**	**2885**	**2846.6**	**3054.2**	**2836.7**	**3004.5**	**3077.8**

It can be concluded that the structure of electricity production was quite uneven during the observed period. However, it is obvious that the most significant production of electricity is by hydropower plants, except in 2017 and 2020, and that it amounted to a maximum of 59.7% of the total electricity produced in 2016. The share of thermal power plant (TPP Pljevlja), was on average at the level of about 35-45% of the total electricity produced. According to the plan for 2022, it is predicted that the most significant share in electricity production will continue to be from hydropower plants (53% from hydropower plants compared to 37% from thermal power plant from the total planned production), while the remaining 10% of electricity would be produced in wind farms and solar power plants.

In the observed period, Montenegro was mainly import dependent on electricity, except in 2018 and 2021 when it had a surplus, and these imports varied significantly due to different circumstances. According to the plan for 2022, the import of electricity is planned at the level of less than 2% of the total needs. Finally, it should be noted that the total amount of final energy for consumption is affected, in addition to consumption in the energy sector, by significant transmission losses.

Previously presented data within the Energy Balance served as a basis for the projection of electricity production by hydropower plants in the base case scenario - the scenario "without climate change".

Table xx – Projection of electricity production by hydropower plants in the scenario "without climate change"“

Table 17 Production of electricity by hydropower plants (GWh)

Year	Production of electricity by hydropower plants (GWh)
2025	1,847
2030	1,894
2035	1,942
2040	1,991
2045	2,041
2050	2,093
2055	2,146
2060	2,200
2065	2,255
2070	2,312
2075	2,371
2080	2,431
2085	2,492
2090	2,555
2095	2,619
2100	2,699

After the projection of electricity production in hydropower plants, it is necessary to assess the impact of climate change on this production for different projected time periods, as well as for the appropriate climate scenarios. As for the previous sectors, four scenarios were considered:

1. Near future, reduction of electricity production - hydropower plants by 2050 by 5% (NF1),
2. Near future, reduction of electricity production -hydropower plants by 2050 by 10% (NF2),
3. Far future, reduction of electricity production - hydropower plants by 2100 by 10% (FF1),
4. Far future, reduction of electricity production - hydropower plants by 2100 by 15% (FF2).

Calculation of the reduction of electricity production in hydropower plants due to the effects of climate change was performed on the basis of the previously determined data, as presented in the following table:

Table 18 Projection of reduction of electricity production by hydropower plants, due to the effects of climate change (GWh)

Year	NF1	NF2	FF1	FF2
2025	10	19	7	10
2030	27	52	19	27
2035	44	88	31	46
2040	63	126	44	65
2045	83	166	58	86
2050	105	209	73	108
2055			88	131
2060			105	155
2065			122	181
2070			140	208
2075			159	236
2080			179	266
2085			199	298
2090			221	331
2095			244	366
2100			270	405
Total	**1,440**	**2,860**	**9,236**	**13,758**

The reduced amount of electricity produced would have to be offset by imports. Electricity import prices have varied extremely in the previous period, not only long-term, but also during, for example, 2021. „Elektroprivreda Crne Gore“ (EPCG) announced that in 11 months in 2021, it spent twice as much on imports than in the same period last year, i.e. 60 million EUR. EPCG imported almost the same amount of electricity in 2021 and 2020, but in 2020 the average price was EUR 38 per MWh, while during the last year (2021) the price was EUR 90 per MWh.

Prices on European and regional electricity exchanges currently range from 120 EUR per MWh in Germany and Poland to 280 EUR per MWh in Switzerland, an increase of about 90% since the beginning of the year. On the stock exchanges in the region, in Croatia, Serbia and Greece, prices range from 215 to 220 EUR per MWh. Of course, the companies in charge of procuring electricity, and thus EPCG, do not have to procure it, and usually do not do so on the stock exchanges, but usually announce their tenders for deliveries for several months. In these situations, lower prices are obtained than those on the stock exchanges, but if urgent imports are needed, for a shorter period of time, then prices go up significantly. Thus, the prices of emergency deliveries for January 2022 are around 240 EUR, and the agreed prices for the whole next year are around 120 EUR per MWh. Prices also depend on the financial situation of the company and its history of payment or non-payment of debts.

For further assessment, prices were increased in accordance with projected growth rates from the document „*World Energy Outlook*“, 2021.

Table 19 Projected growth rates

2020 – 2030	2030 – 2050
2.3%	1.5%

Taking into account that in this document growth rates are presented until 2050, covering the near future scenario, the growth rate used for the distant future scenario, until 2100, was calculated in accordance with the trend from the previous period.

Due to the reasons stated above, related to fluctuations of electricity import prices, it is not possible to determine with certainty its value as a basis for further calculations (especially in such a long period of observation), so it was decided to conduct further analysis in three variants. The basic variant of the analysis would be the existing contract price of electricity imports for 2022, in the amount of 120 EUR per MWh. The other two variants would be one higher and one lower (160 and 80 EUR per MWh, respectively), in order to gain an overview of the future price fluctuations in a certain way. An estimate of economic damage of reduced electricity production in hydropower plants, due to the effects of climate change, in the basic variant, is shown in the following table:

Table 20 Estimate of economic damage of reduced electricity production by hydropower plants, due to the effects of climate change, basic variant (EUR)

Year	NF1	NF2	FF1	FF2
2025	1,215,999	2,381,354	852,048	1,250,505
2030	3,741,152	7,357,131	2,618,000	3,847,789
2035	6,743,990	13,318,035	4,713,170	6,937,080
2040	10,358,742	20,542,727	7,229,922	10,656,654
2045	14,683,379	29,242,379	10,234,855	15,107,551
2050	19,829,997	39,659,994	13,804,033	20,405,396
2055			18,024,256	26,682,384
2060			22,994,492	34,089,519
2065			28,827,490	42,799,157
2070			35,651,607	53,007,875
2075			43,612,862	64,939,707

2080			52,877,257	78,849,810
2085			63,633,385	95,028,596
2090			76,095,381	113,806,400
2095			90,506,235	135,558,747
2100			107,674,573	161,511,859
Total	**240,527,417**	**477,782,265**	**2,672,886,960**	**3,986,518,933**

Elaborated future economic damage in the water sector due to the effects of climate change could be significant, especially considering that only the damage due to reduced electricity production was analyzed and that by including estimate of other damages, this amount could be higher.

In the near future scenarios, these damages could be around EUR 20 to 40 million per year in the final year of the observation, which would be cumulatively around EUR 240 to 480 million for the total observed period. In the distant future, these damages in the final years would be from about 107 to about 161 million EUR per year, so the total amount of these damages for the total period up to 2100 would be from about 2.7 to 4 billion EUR.

The following two tables show the projections of economic damage of reduced electricity production in hydropower plants, due to the effects of climate change, in alternative variants.

Table 21 Estimate of economic damage of reduced electricity production by hydropower plants, due to the effects of climate change, variant with lower price (EUR)

Year	NF1	NF2	FF1	FF2
2025	810,666	1,587,569	568,032	833,670
2030	2,494,101	4,904,754	1,745,333	2,565,193
2035	4,495,993	8,878,690	3,142,113	4,624,720
2040	6,905,828	13,695,151	4,819,948	7,104,436
2045	9,788,920	19,494,919	6,823,237	10,071,700
2050	13,219,998	26,439,996	9,202,689	13,603,597
2055			12,016,171	17,788,256
2060			15,329,661	22,726,346
2065			19,218,326	28,532,772
2070			23,767,738	35,338,583
2075			29,075,242	43,293,138
2080			35,251,505	52,566,540
2085			42,422,257	63,352,398
2090			50,730,254	75,870,934
2095			60,337,490	90,372,498
2100			71,783,048	107,674,573
Total	**160,351,611**	**318,521,510**	**1,781,924,640**	**2,657,679,289**

Table 22 Estimate of economic damage of reduced electricity production by hydropower plants, due to the effects of climate change, variant with higher price (EUR)

Year	NF1	NF2	FF1	FF2
2025	1,621,332	3,175,139	1,136,065	1,667,340
2030	4,988,203	9,809,508	3,490,667	5,130,386
2035	8,991,987	17,757,380	6,284,226	9,249,441
2040	13,811,656	27,390,302	9,639,896	14,208,872
2045	19,577,839	38,989,838	13,646,474	20,143,401
2050	26,439,996	52,879,992	18,405,378	27,207,195
2055			24,032,342	35,576,511
2060			30,659,322	45,452,691
2065			38,436,653	57,065,543
2070			47,535,476	70,677,167
2075			58,150,483	86,586,276
2080			70,503,009	105,133,080
2085			84,844,514	126,704,795
2090			101,460,508	151,741,867
2095			120,674,980	180,744,996
2100			143,566,097	215,349,145
Total	**320,703,222**	**637,043,020**	**3,563,849,280**	**5,315,358,578**

As presented, the total economic damage of reduced electricity production in hydropower plants, due to the effects of climate change by 2100, in the case of higher electricity import prices in the future, could exceed EUR 5 billion, which for a small country like Montenegro certainly represents a significant amount.

5.2. Economic vulnerability assessment of fluvial floods

Flood damage monetary value estimates were generated for all Montenegro's watershed employing updated stage damage curves. Damage assessments were generated for eight return frequencies including: 1:2 year, 1:5 year, 1:10 year, 1:25 year, 1:50 year, 1:100 year, 1:500 year and 1:1000 year, which allowed for the computation of average annual damage monetary values.

In recent years, an increasing number of studies have used land cover characteristics and water depth-damage functions for the assessment of the economic impacts of flood risk, which is the most common methodology for the estimation of damage monetary value (Alfieri et al., 2016). A depth-damage function provides the relationship between water depth and monetary damage for a specific land use type. The intersection of flood extension maps (with water depth) with land use maps of the flooded area enables the calculation of direct damages of a flood event (due to physical damage to buildings, inventories, industry and infrastructure). Flood risk evaluation studies and assessment of the economic impacts of floods are necessary for assessing the effects of flooding (Genovese, 2006).

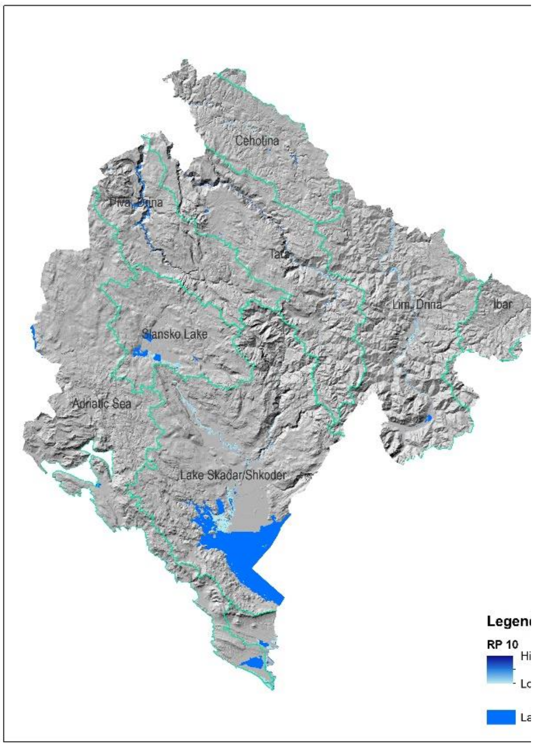


Figure 32 Flood hazard maps of Montenegro for 10 years return period

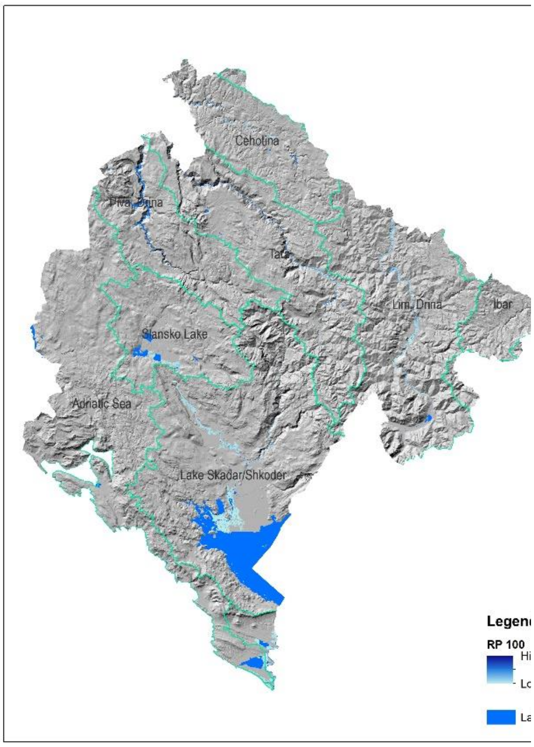
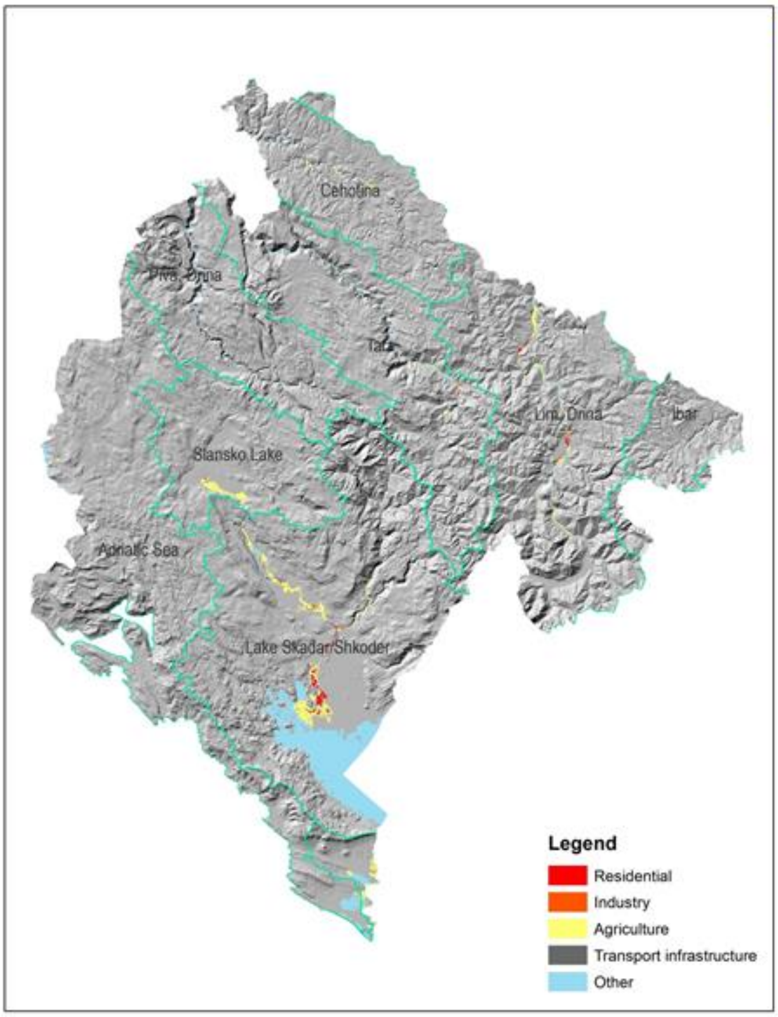


Figure 33 Flood hazard maps of Montenegro for 100 years return period

For this purpose, flood hazard maps from EU Commission (Joint Research Centre Data Catalogue) and Geographic Information Systems (GIS) were used to assess the effects of flooding. The results obtained from flood hazard maps containing inundation extent and water depth level were further processed in GIS environment using additional data such as CORINE land cover, land cover from topographic maps on a scale of 1:25.000 and other SHP files for transport infrastructure network (roads and railway).



Code (GIS)	Description
E0	Urban area
E1	Commercial and indus
E2	Agricultural area
E3	Transport

Figure 34 Flood risk map of Montenegro for 100 years return periods

For the 1:100 year flood, total possible flooded area on the Montenegro's watersheds is estimated at ~10.000 ha, most of which is associated on agricultural land 84%.

Table 23 Flood risk areas

Area (ha)	Adriatic Sea	Buna/Bojana	Ćehotina	Lake Skadar	Lim, Drina	Piva, Drina	Slansko Lake	Tara	**Montenegro**
Residential	46.8	3.1	3.1	1,050.6	238.6	0.0	15.1	40.7	**1,398**
Industrial	0.0	0.0	1.2	30.1	50.8	0.0	0.0	0.0	**82**
Agriculture	190.0	730.8	287.6	4,408.4	1,354.5	13.1	1,068.8	310.7	**8,364**
Infrastructure	2.9	1.4	11.5	67.0	43.3	1.3	1.5	3.5	**133**
Total	**239.7**	**735.4**	**303.3**	**5,556.1**	**1,687.2**	**14.4**	**1,085.5**	**354.9**	**9,976**

For consistency purposes in flood risk assessment amongst European River Basin Districts the European Commission's Joint Research Centre (JRC) – Institute for Environment and Sustainability developed a damage function dataset for all EU countries, including maximum damage values for each land use type. This dataset contains flood damage functions which are developed at a continent level and the maximum damage values are provided at a country level, and both are specified for six impact categories: residential, commercial, industrial, transport, infrastructure, and agriculture. For cases if it was not feasible to develop a continent-specific damage function a Global damage function is provided which can be applied. JRC's damage function are mostly based on full replacement cost.

According to the Global flood depth-damage functions database, the following values are proposed for Republic of Montenegro.

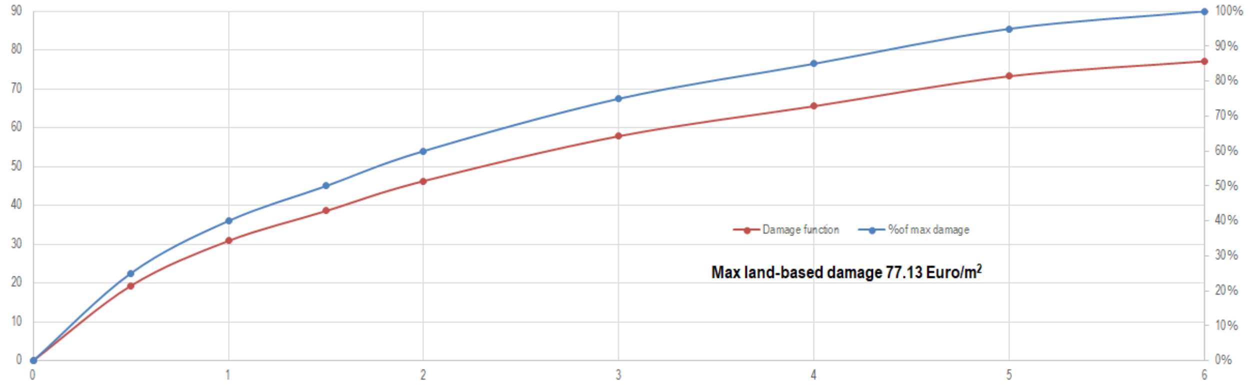


Figure 35 Residential flood depth-damage function

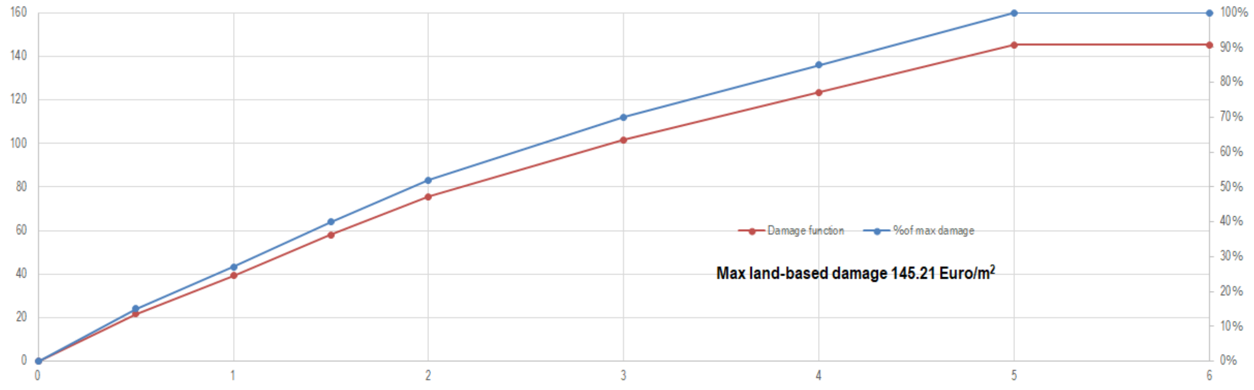


Figure 36 Industry flood depth-damage function

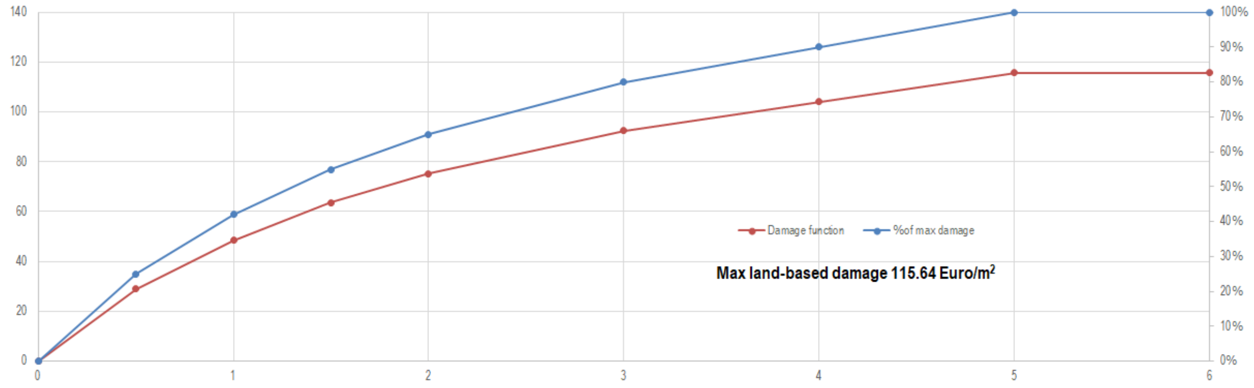


Figure 37 Transport infrastructure flood depth-damage function

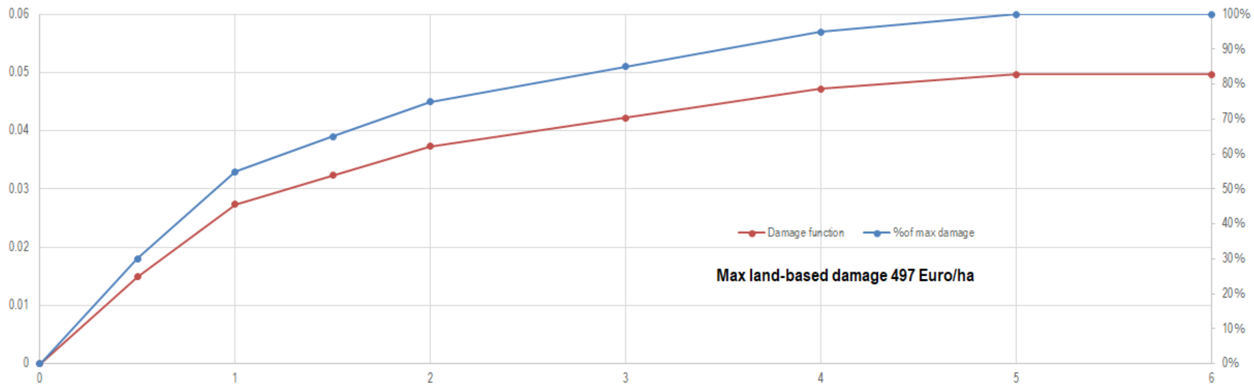


Figure 38 Agriculture flood depth-damage function

The direct economic impact is a function of the type of land use flooded (damage value per each land use and country specific), the level of damage (damage factor, based on water depth), and the extension of the flooded area by land use type.

$$\text{Direct economic impact} = \sum_{i=1}^{4} \text{damage value} \times \text{damage factor} \times \text{extension of flooded area}$$

Where i = land use type: residential buildings (1), commercial and industrial (2), agriculture (3), transport infrastructure (4)

Based on the proposed methodology, for all sub-watershed in Montenegro, the direct potential damages from synthetic flood episode with 100 years return period are calculated.

For the 1:100 year flood, total direct damages in Montenegro are estimated at around 583 million euros, which represents 12.8% of Montenegro's national GDP.

Table 24 Total damages for all sub-watersheds in Montenegro

	Adriatic Sea	**Buna/Bojana**	**Ćehotina**	**Lake Skadar**	**Lim, Drina**	**Piva, Drina**	**Slansko Lake**	**Tara**	**Montenegro**
Residential	15,612,485	1,077,533	1,021,273	342,403,277	84,218,733	/	5,773,352	14,460,126	**464,566,779**
Industrial	/	/	504,239	15,297,253	26,379,048	/	/	/	**42,180,539**
Agriculture	53,601	217,859	87,617	1,235,617	400,234	4,232	338,464	96,785	**2,434,409**
Infrastructure	1,516,025	795,410	6,873,706	34,979,797	25,701,259	706,182	891,047	2,014,690	**73,478,114**
Total	**17,182,111**	**2,090,801**	**8,486,835**	**393,915,944**	**136,699,273**	**710,414**	**7,002,863**	**16,571,601**	**582,659,842**

With this approach, the estimated total direct damages for different return periods, for all sub-watersheds in Montenegro, are as follows:

Table 25 Total direct damages for different return periods, for all sub-watersheds in Montenegro

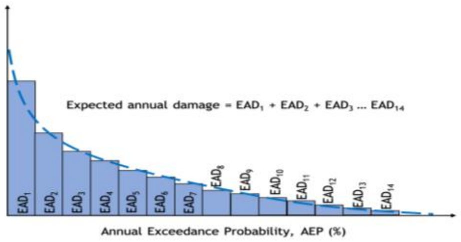
Return period	**Probability**	**Flooded area**	**Direct economic impact**
Years	%	ha	Euro
1,000	0.1%	13,025	1,654,000,000
500	0.2%	12,096	1,062,000,000
100	1.0%	9,940	583,000,000
50	2.0%	9,011	500,000,000
25	4.0%	8,083	419,000,000
10	10.0%	6,855	294,000,000
5	20.0%	5,927	194,000,000
2	50.0%	4,699	110,000,000
1	100.0%	3,770	0

According to the analysis in the document, a 100-year flood event, could cause state-wide damage of 10% of national GDP and affect more than 60,000 people (The model results of risk profile are based on population and gross domestic product (GDP) estimates for 2015).

An **expected annual damage (EAD)** is the expense that would occur in any given year if monetary damages from flood hazard probabilities and magnitudes were spread out equally over time. This does not mean that each year will produce the same damages from natural hazards. Rather, some years will have high damages, while others will have minimal damages, but overall there is a monetary impact one should expect to incur over time[57].

In general, the events with the lowest annual exceedance probabilities are associated with the highest total damages (rare = costly!).

The expected annual damages (EAD), are calculated based on following equitation:



$$\int_a^b fd * fp$$

a & b - annual exceedance probabilities

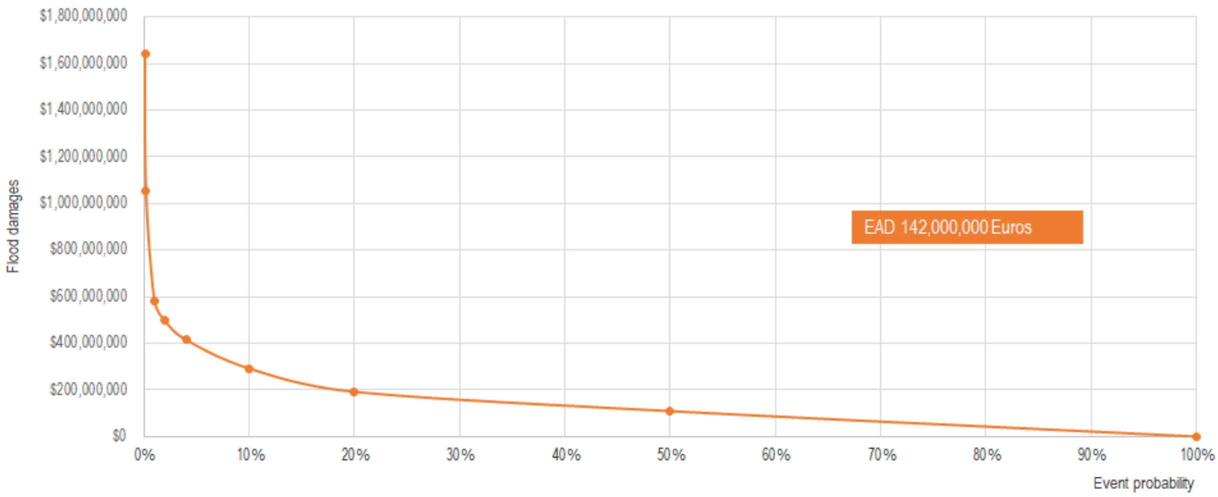


Figure 39 The expected annual damages (EAD) from synthetic flood episodes

Based on the proposed methodology, for all sub-watershed in Montenegro, **The expected annual damages (EAD)** from synthetic flood episodes with different return period are estimated on 142 million euros.

Result interpretation an findings

Although Montenegro can be exposed to all kinds of floods, two categories of floods are characteristic:

- Fluvial floods which are result of abundant rain series of a few days with a large amount of rainfall, which in extreme cases can reach about 500~1000 lit/m^2, covering larger space. They connect with river systems and lakes in such a way that water levels have extremely high values; they rarely occur, and when they occur, certain thresholds are reached and exceeded.
- Meteorological floods (pluvial and flash floods) which are local; they are more likely to occur and they are related to torrents and urban environments or a certain fragment of space. They

[57] https://storymaps.arcgis.com/stories/7878c89c592e4a78b45f03b4b696ccac

are of short time span, but can be very aggressive, destructive and difficult to foresee and locate in time and space, because they are related to the formation of storm-thunder clouds which are very dynamic and capture only a certain locality from which, in a very short time, an abundant amount of rain is excreted, which in only a few hours can reach over 100 lit/m2 and thus very often exceeds the thresholds.

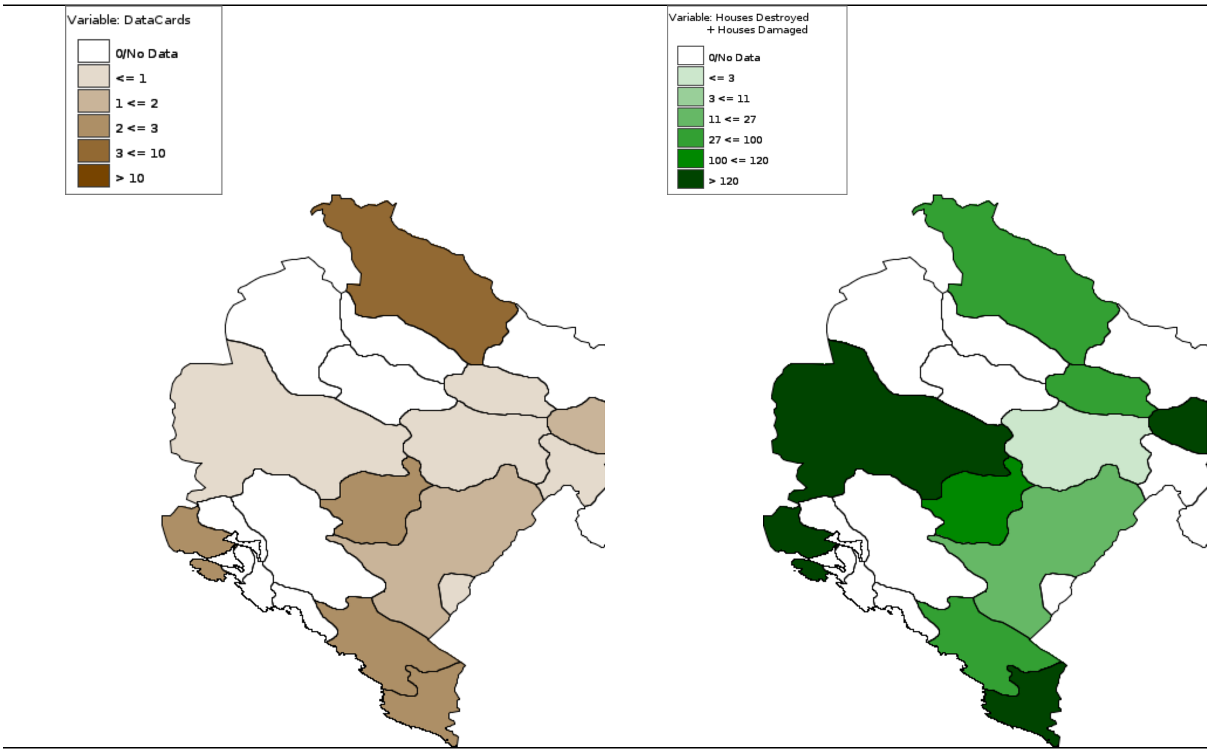
The largest floods in Montenegro since the half of the past century until now have occurred in: 1963, 1979, 1999, 2000, 2010 and 2011.

The EM-DAT Disaster Database has documented 4 flood disasters in Montenegro from 2000 to 2011. These floods have affected around 8000 people. The damage and losses caused by the 2010 flood alone amounted to around €44 million (1.4% of gross domestic product) (EM-DAT, 2019).

The FAO estimated that this flood impacted around 30,000 hectares of agricultural land. The most affected was the area around the River Zeta valley and the area around Lake Skadar, specifically the territory of Golubovci, where most of the national vegetable production occurs. Total agricultural damages and losses were estimated at over €13 million, of which over €6 million was in damages and over €7 million was in losses (FAO, 2015).

The most recent significant flood was in November 2019 resulting in multiple impacts for people and infrastructure in municipalities of Nikšić and Kolašin. The total estimated damage on households from this flood was around €73,000 and for infrastructure (e.g. roads, bridges) it was around €211,500.

The UN-DRR Disaster Information Management System has documented 34 flood events in Montenegro from 2005 to 2018, with 1264 damaged houses, over 550 evacuated population and 4.500 ha flooded agricultural land.



Flood events and damaged houses - UN-DRR Disaster Information Management System

In Montenegro, protection from floods has not been given much attention so far, although the consequences are frequently significant. The scope of work performed so far on the arrangement of watercourses and flood defense on all watercourses in Montenegro is very modest and they were mostly performed in the 70s of the last century. Due to the partial approach to this issue, most of the constructed structures are of a local character, so the lengths of defensive embankments, coastal fortifications and regulated riverbeds are very short - from a few hundred meters to 1-2 kilometers. A special problem is the weak and irregular maintenance of flood defense facilities, which inevitably led to a reduction in the level of protection of coastal areas. Larger defensive units were realized only along Moraca (embankment Cijevna-Vranjina 16 km long and three more sections 3-5 km long) and along Bojana (three sections of the embankment, 3-6 km long). Certain works have been carried out since 2011 in order to repair the consequences of the floods that occurred in 2010, as a prevention of future floods.

The analyzes show that expected annual damages (EAD) from flood episodes with different return period are estimated on 142 million euros, which represents 12.8% of the national GDP, and is in line with the document of the World Bank regarding the possible economic damages from floods of national level. The Skadar and Drina basins stand out as the most critical.

Following the recommendations of the Sendai Framework for Disaster Risk Reduction 2015-2030 (adopted at the Third UN World Conference in Sendai, Japan, on March 18, 2015), activities related to flood risk reduction are recommended, according to the following prioritization:

Priority 1. Understanding disaster risk (Know your risk): Focused on the degree of awareness and understanding of Disaster risk management (DRM) concepts and practices of all stakeholders involved in the DRM system at all levels. A good level of understanding of DRM at both strategic/ policy level, as well as at operational level is a prerequisite of informed decision - making on DRM in any given country. Overall, the proposed measures focus on consolidating existing risk data, information, and mapping undertaking in various institutions, and at various levels (especially at the local level) with *support from partners. Capacity building of key institutions, in various areas related to DRM emerged as a key area covering several recommendations. Based on the consultations with the national stakeholders, the following measures are singled out as priorities:* Identification and assessment of flood hazards and flood risks; Erosion mapping; Landslide hazard and risks maps; Rainfall and discharge monitoring; Landslide monitoring;

Priority 2. Strengthening governance to manage disaster risk (Risk governance): outlines the requirements of an effective legislative, policy and institutional system for DRM as enabling factors for the implementation of DRM measures. Key recommendations related to disaster risk governance at national and local level, focus on validating and enforcing legislative and institutional reform. *Based on the consultations with the national stakeholders, the following measures are singled out as priorities:* Legal documents, legislations, standards and norms; Legislative regulation of the activities of local authorities for limitation of construction, including illegal construction and construction close to the floodplain areas; Improving legislation for urban planning; Development and application of new legal documents and standards for flood protection; Updating the norms for dimensioning sewage networks, Preaparation and update of Flood Risk Management Plans;

Priority 3. Investing in economic, social, cultural, and environmental resilience (Risk reduction and increasing resilience): centered on the planning and implementation of structural and non-structural measures at sector level to reduce the risk arising from disasters and increase the resilience of at-risk populations. *Based on the consultations with the national stakeholders, the following measures are singled out as priorities: Non-structural measures:* Improving land use pattern and afforestation to obtain water retention effect; Afforestation and management of bare lands in the catchment area (zones with high erosion); Protection of river coasts and beds from erosion and sand extraction, including biological support; Restriction or prohibition on the extraction of inert materials from the river bed;

Priority 4. Enhancing preparedness for effective response, and building back better in recovery and reconstruction (Preparedness for response and recovery): with specific focus on structures, tools and operational capacities related to disaster preparedness, response, recovery, rehabilitation and reconstruction. When the risk of disasters cannot be reduced, transferred or managed, capacities are needed in order to prepare for, respond to and recover from the impact of disasters. *Based on the consultations with the national stakeholders, the following measures are singled out as priorities:* Improvement of the existing meteorological, hydrological and weather forecast monitoring systems; Developing early warning system; Increasing public awareness, preparation and involvement; Actions during floods and after the flood; Provide adequate funding for DRM at national level in line ministries, and at local level

6. Priority actions that address climate-driven vulnerabilities and gender disaggregated impacts

a. Policy level – planning, monitoring, financing

- Define, legally regulate and institutionalise the national climate adaptation planning processes.
- Develop a Long-Term Strategy on Climate Action which is in line with the EU requirements and prospects for climate action until 2050.
- Prepare and adopt a comprehensive National Climate Change Adaptation Strategy and Action Plan with significant emphasis on the water sector
- Introduce evidence-based float protection action plans
- Development and constant promotion of general guidelines for the population regarding torrential and flesh floods and other extreme events related to the water sector
- Establish an intersectoral body and process to monitor the impact of climate change on the water sector and the human health in general, as well as to monitor the development and implementation of the relevant national policy documents
- To establish an integrated (intersectoral) information system, with timely, spatially and gender (where applicable) disaggregated data/information related to the qualities and quantities of the underground and ground water bodies, as well as extreme events related to the water sector
- Introduce a special fund for dealing with climate change and climate extremes.
- Develop gender responsive, cross-sectorial and coherent policies relevant for the water sector and its climate adaptation.

b. Water infrastructure

- Water utilities to improve the quality of data by measuring the amount of affected water, establish measurement of water consumption, continuously record and enter data on utility infrastructure into the Geographic Information System (GIS), record and classify failures that occur on the infrastructure, record the reasons and duration of all interruptions in the provision of services to customers, collect data on customer complaints, etc.
- Protect drinking water sources and designate sanitary zone protection.
- Provide financial resources for the construction of a new and expansion of the existing sewerage network, since there is a big disproportion between the level of water supply and sewerage network.
- Creation of the set of gender-sensitive indicators based on the existing practices on collecting sex-disaggregated data upgraded with the international sets of gender indicators (SDGs);
- Capacity building on the methods and instruments for collecting sex-disaggregated data, as well as monitoring and reporting through design of gender indicators.
- To introduce an Early warning system during the weather extremes and prepare the relevant institutions and the population for appropriate response;
- To enhance the knowledge and the skills of the water sector policy making level regarding the climate change impact/risks on the water resources.
- Urgently invest in measures for disaster risk mitigation for the relevant river basins in the country

- Conduct as many as possible climate change and water/health field research studies on prioritized risks per specific regions and micro locations (flood, drought) with aim to assess the level of risk and impact and future impact
- Enhanced mmonitoring and assessment -the water utilities and the healthcare facilities should have sufficient information regarding water, sanitation, chemical use, healthcare waste management, and energy services considering climate resilience and environmental sustainability.
- Water safety and security, sanitation, chemical safety and health care waste regulations should be designed and implemented taking into consideration climate change variability and impact over time, as well as environmental sustainability.
- Activities should be introduced for adaptation of the current systems and infrastructures through building regulations implemented in the construction and retrofitting of water infrastructure to ensure climate resilience and environmental sustainability.
- New digital technologies should be promoted to enhance the capacities of the water sector and their outreach to the general population related aspects related to climate adaptation
- Facilities should have established a special procedures and budget for emergency preparedness and response to climate hazard

c. Specific actions for monitoring and addressing climate-driven vulnerabilities and gender and socially disaggregated impacts:

- Collection of sex-disaggregated data on policy, program, project level in the water sector related to gender-based vulnerability assessment in terms of creation gender-responsive adaptive solutions,
- Analysis of sex-disaggregated data in corelation with other types of vulnerabilities in relation to droughts, food, nutrition, water sufficiency and management, adaptive food related practices, as well as water-bounded diseases.
- Setting up an institutional and operational structure (procedures) for gender mainstreaming (collecting sex-disaggregated data, provision of a systematic gender analysis, ensuring gender-responsive policy design, monitoring and reporting)
- Gender-responsive budgeting to support adaptation measures targeted to address the gender-based vulnerabilities.
- Collection of sex-disaggregated data on policy, program, project level in the water sector related to gender-based vulnerability assessment in terms of creation of gender-responsive adaptive solutions;
- Analysis of sex-disaggregated data in corelation with other types of vulnerabilities in relation to heat waves, droughts, food, nutrition, water sufficiency and management, adaptive food related practices, indoor and ambient pollution and health risks, which are a combination of psychological, biological, behavioural, and social factor.
- Design of gender responsible adaptation measures attributed to floods;
- Design of gender responsible adaptation measures for owners and workers in agricultural holdings and unpaid labour force;
- Design and implementation of measures for preventing health hazards by the water consumption and water usage;

- Preventive and protective measures for women who are in the unpaid family labor, women are the primary users and managers of water for the cooking, cleaning, care for children and elderly, sanitation, and health.
- Water and irrigation activities and plans to be developed based on the different needs of women in agriculture sector as more represented in the family unpaid labor and are mostly involved in the irrigation activities related to the cultivation of crops – mostly near the home, and nurturing livestock for their own and small-scale commercial needs;
- Water and irrigation systems to be developed in compliance to the needs of holders of individual agricultural holdings and managers (men);
- Provision of access to water (basic, improved water services, and accessing water in sufficient quantities) for the poorest population Roma and rural population
- Development of climate-resilient water supply system and sanitation services and facilities focusing on gender, children, youth and overall social inclusion;
- Disaster risk reduction and management program: Development and implementation of gender responsive and social inclusive local disaster and climate resilience plans, and establishment of gender responsive and social inclusive sensitive early warning systems

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