Ministry of Nature Protection of Republic of Armenia

VULNERABILITY OF WATER RESOURCES IN THE REPUBLIC OF ARMENIA UNDER CLIMATE CHANGE

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Republic of Armenia

This report aims to highlight the vulnerability of water resources of Armenia to climate change and possible economic consequences and includes compilation of studies developed within the framework of “Enabling Activities for the Preparation of Armenia’s Second National Communication to the UNFCCC” UNDP/GEF/00035196 project implemented by UNDP Armenia and executed by Ministry of Nature Protection of the Republic of Armenia.

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1. SUMMARY

The Republic of Armenia lies in the North-East of the Armenian Highland at the turn of Caucasus and Western Asia. It borders with Georgia in the North, Azerbaijan in the East, Turkey in the West and South-West and with Iran in the South. The RA territory is 29743 km^2. The greatest extension of the territory from South to North is 360 km and 200 km from West to East.

According to the land balance data of 2006, the territory of the country is divided into the following categories: 71.6% - agricultural lands, 12.5% - forests (10.4% - covered with forest), 7.4% - specially protected nature areas, 0.9% - water surface, 5.4% - settlements, industry and communications territory, 1.3% - other areas.

Armenia's territory is notable by its developed and irregular hydrological system typical to mountainous countries. It accommodates around 9500 small and medium rivers, the total length of which is 25 thousand km. The longest rivers are: Araks (1072 km), Vorotan (179 km), Debed (178 km) and Hrazdan (146 km). The average annual flow of surface waters is about 6.8 km^3. The flow of ground waters is approximately 4.07 km^3, exploited approved reserves (1200 km^3). The density of rivers network varies significantly across the country (0-2.5 km/km^2).

The greatest lake of Armenia is Sevan – one of the largest high-mountain fresh-water lakes. Presently, the level of the lake is 1898 m, the surface area – 1257 km^2, the volume – 33.4 km^3. Armenia also has 100 small mountainous lakes, with the total volume of 0.8 km^3.

Studies based on meteorological observation data show that Armenia has been warming during the last decades. The increase of annual air temperature by 0.85 ^{0}C and reduction of precipitation by 6% during last 80 years has been revealed. However, the changes of temperature and precipitation vary from region to region and from season to season. Thus, in summer the temperature has increased by 1^{0}C during the period 1935-2007, whereas in winter the increase is not statistically significant – about 0.04^{0}C. The forecasts for Armenia show a significant and consistent increase in temperatures projected for the three time slices: 2030, 2070 and 2100. The increase of air temperature will be maximal in summer season. The central and western regions of Armenia shall experience more warming than the rest of the region in the country. Annual temperatures will rise by 4-6^{0}C by the end of 21st century.

Increased air temperature and lower precipitation will increase evaporation rates and reduce winter snowpack and spring run-off: as a result less water reaches streams and rivers. Climate change will reduce river flow, lake levels and, eventually, groundwater reserves. Armenia's total river flow is projected to drop 7 percent by 2030 and 24 percent by 2100. The main source of Lake Sevan's chilly alpine waters is spring snowmelt supplied through 28 rivers and streams that flow into the lake, which are expected to decrease by 41 percent in flow by 2100; as a consequence, Lake Sevan's water level is expected to fall over time. Further, it must be taken into account that due to reduction in water resources and projected growth in air temperature, the quality of water in Armenia's rivers and lakes is expected to deteriorate.

Vulnerability of Armenia's water resources due to climate change will also have socio-economic implications. Armenia's agriculture sector, which accounts for 20 percent of GDP in direct agricultural production and an additional 10 percent of GDP in food manufacturing, is highly dependent on irrigation water from rivers, many of which will suffer large-scale reductions in flow as climate change progresses. Half of Armenia's arable land requires irrigation; with climate change more land will fall under this category but less river water will be available. Crops, which are more vulnerable to drought than pastures and far more likely to require irrigation, represent 14 percent of GDP. A 25 percent reduction in river flow is projected to result in a 15 to 34 percent reduction in the productivity of irrigated cropland, with an average estimated reduction of 24 percent. The expected loss in yield for grapes would be 21 percent and for winter wheat, 25 percent. Total losses to the agricultural sector would amount to 65 to 145 billion AMD, or US$180 to 405 million (with an average impact of 105 billion AMD or US$293 million); this would be a loss of 2 to 5 percent of GDP (3 percent on average).

Depending on policy choices, reductions in agricultural production could also impact on Armenia's food production industry and thereby have a wider-reaching effect on the economy. If agricultural losses result in losses to the food production industry of the same scale – 13 to 34 percent reduction – the additional decrease to GDP would range from 1.5 to 3.4 percent.

Vulnerability of water resources will also affect the energy sector, since Armenia depends on its rivers to provide power generation to its hydro-electric plants and cooling water to its nuclear and thermal generation plants. As the flow rates of Armenia's rivers decline with climate change, the country's ability to meet its full domestic electricity demand will be at greater risk. If water reserves and releases are well managed, small changes in precipitation and evaporation need have little impact on hydro-electric generation. Regrettably, the projected changes to Armenia's river flows are neither small in scale nor temporary. Reduced river flow coupled with an increased demand for irrigation water is very likely to reduce electricity generation from these plants.

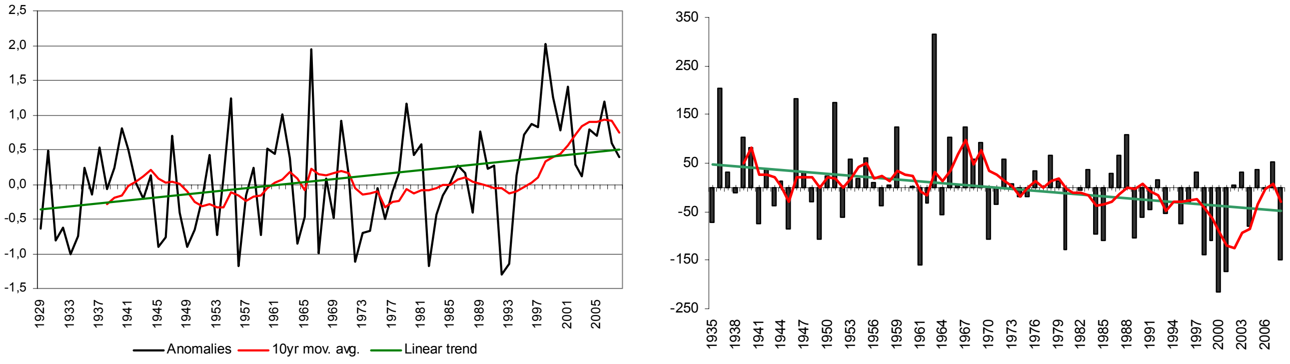
Given the intensification of anomalies with air temperature and atmospheric precipitation due to climate change, the damage caused by floods and mudflows has increased in recent years. It is expected both occurrence and intensity of floods and mudflows will increase in the country.

Thus, the country needs to prepare for future water shortages through anticipatory adaptation, including both private and public measures, such as investments in large-scale infrastructure projects to increase Armenia's capacity for water storage and limit losses from inefficient distribution systems. In addition, managing water shortage in real time, which represents reactive adaptation, shall also be implemented. Particularly, if water demand exceeds water supply, the state can and must allocate water among different users according to the priorities set by the Republic of Armenia Water Code and Law "On Fundamental Provisions of the National Water policy", including use by households, irrigation, energy production and industry.

2. CLIMATE CHANGE IN ARMENIA

2.1. Actual climate and analysis of its observed changes before 2007

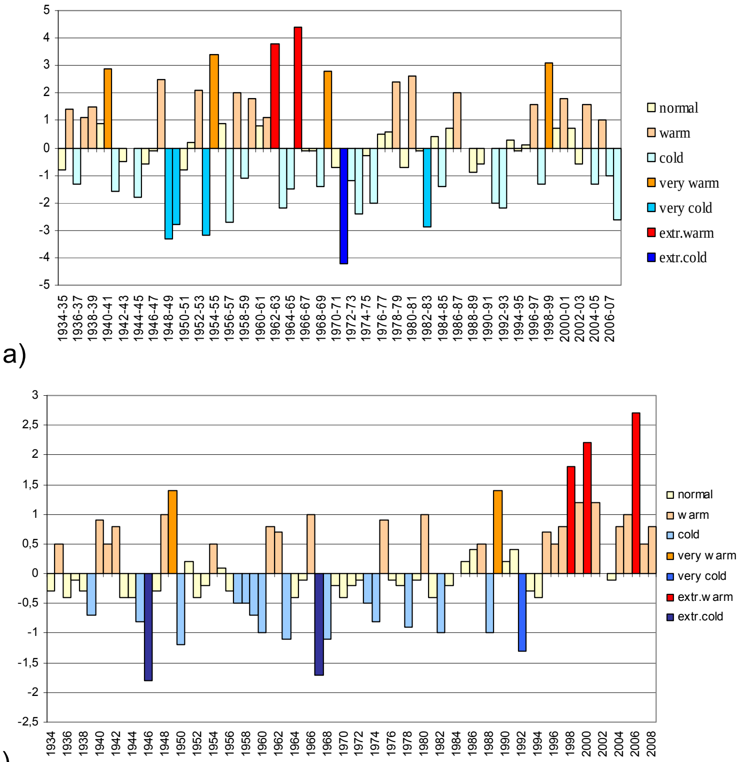
Studies based on meteorological observation data show that Armenia has been warming during last decades. The anomalies of annual air temperature (fig.1a) and total precipitation (fig.1b) for 1935-2007 over Armenia have been estimated with respect to the base period 1961-1990.



a) b)

Figure 1: Observed annual air temperature (a) and precipitation (b) anomalies compared to 1961-1990 baseline mean (black line), their decadal moving averages (red line) and linear trends (green line)

The increase of annual air temperature by 0.85 ^{0}C and reduction of precipitation by 6% during last 80 years has been revealed. The anomalies of temperature during last 14 years are positive, and the year 1998 has been the warmest in Armenia during last 80 years. But the changes of temperature and precipitation vary from region to region and from season to season. Thus in summer (JJA) the temperature has increased by 1^{0}C (fig.2b) during the period 1935-2007, but in winter (DJF) the increase is not statistically significant – about 0.04^{0}C (fig.2a). Persistent positive anomalies of summer temperature have been reported during last 14 years (except 2003), and summer of 2006 was the hottest in Armenia during the period 1929-2007.



a)

b)

Figure 2: Observed winter (a) and summer (b) temperature anomalies with respect to 1961-1990 normal

Variety of hazardous weather and climate events affect the socio-economic sectors and sustainable development in the region. Among the natural hazards, Armenia is mostly affected by droughts, early spring frosts, heat/cold waves, hailstorms, mudflows, landslides, storms, fogs and forest fires (Table.1).

Table 1. Vulnerability of different regions of Armenia to the hydro-meteorological hazards

Marz	Dry conditions /0 – low, 5 – high/	Drought /0 – low, 5 – high/	Seasonal flooding /0 – low, 5 – high/	Hailstorm /0 – low, 5 – high/	Early frosts /0 – low, 5 – high/
Shirak	3	4	3	5	3
Lori	1	0	4	2	0
Tavush	1	0	4	3	0
Kotayk	2	4	1	3	3
Aragatsotn	2	3	2	5	4
Armavir	4	5	0	5	5
Ararat	4	5	2	4	5
Gegharquniq	1	3	4	2	2
Vauots dzor	2	3	4	2	3
Syuniq	1	2	4	2	2

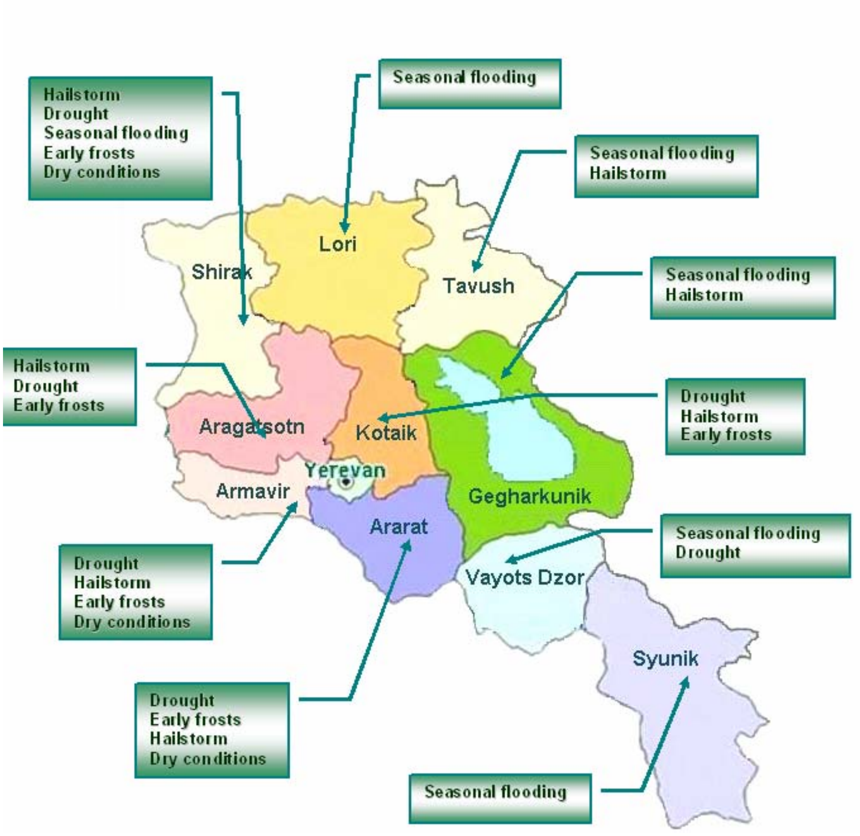


Figure 3. Map of vulnerability of different regions of Armenia to the hydro-meteorological hazards

Note: the hazards scaled from 5 to 3 (among those from 5 to 0)

The analysis shows that their intensity and frequency of extreme weather and climate has increased during last several decades. The recorded number of hailstorms during 2001-2006 reached 46 cases (hailstone diameter 22-35mm, on average); heavy floods during the past decade even resulted in human losses. In 2000, losses of the agriculture sector from droughts amounted in $66.7 million, constituting 10.1% of agricultural gross product. This includes 35% share of potato yield, 20% of cereals, and 16% of vegetables.

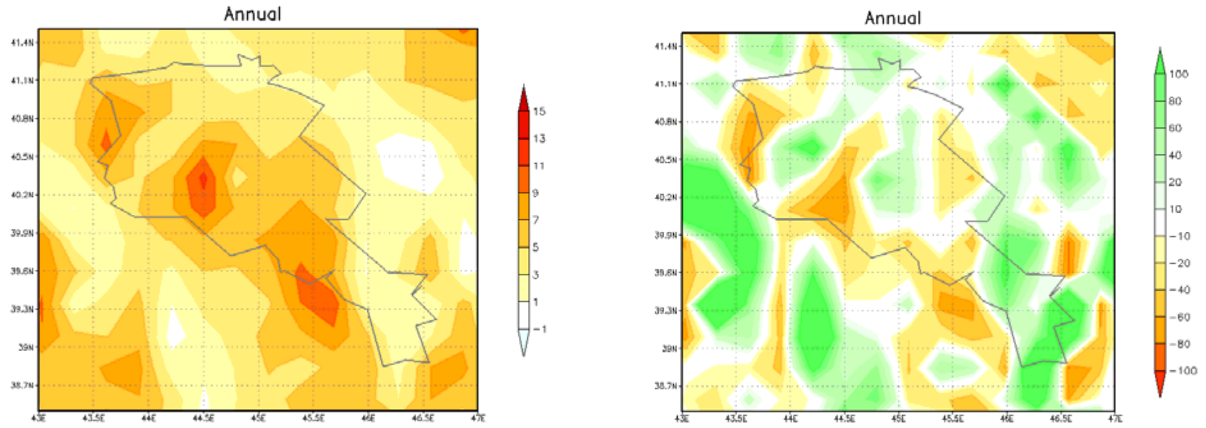
2.2. Climate change projections

The climate change scenarios over Armenia are constructed using the MAGICC/SCENGEN (spatial resolution 2,5° x 2,5 °) and PRECIS software (horizontal resolution 0.22 ° x 0.22 ° based on IPCC A2 and B2 SRES scenarios, The forecasts for Armenia are shown in the Table 2. There is a significant and consistent increase in temperatures projected for the three time slices: 2030, 2070 and 2100 across the various climate models and the ensemble mean. All GCMs expressed an exceptional warming throughout the year; increases in temperatures are somewhat larger for the warm period of year, than the cold one, indicating a continuation, if not intensification, of the trend observed in Armenia during the 20th century. The modeled change in annual precipitation for the period till 2030 was generally less than 10%, which is an insignificant change compared to the large inter-annual variability of precipitation. However, given the large standard deviation the results for annual precipitation should be interpreted with the high caution.

Table 2 Changes in area averaged temperature and precipitation over Armenia (MAGICC/SCHENGEN)

	Temperature deg.C		Precipitation %	
Season	A_2	B_2	A_2	B_2
2030				
Winter	0.9-1.1	0.8-1.0	+4 ÷ -2	+4 ÷ -2
Spring	1.0-1.1	1.0-1.1	-3 ÷ -8	-2 ÷ -8
Summer	1.3-1.4	1.3-1.4	-7 ÷ -12	-7 ÷ -8
Autumn	1.1-1.3	1.0-1.2	0 ÷ -6	-1 ÷ -10
Annual	1.1-1.2	1.0-1.1	-2 ÷ -6	-2 ÷ -6
2070				
Winter	2.6÷2.8	1.8÷2.2	+10 ÷ -6	+5 ÷ -2
Spring	3.0÷3.4	2.7÷3.0	-10 ÷ -22	-8 ÷- 16
Summer	3.8÷4.1	3.3÷3.8	-22 ÷ -35	-18 ÷ -28
Autumn	3.3÷3.6	2.8-3.2	-3 ÷ -18	0 ÷ -10
Annual	3.2÷3.4	2.9-3.0	-6 ÷ -17	-3 ÷ -15
2100				
Winter	4.2-4.7	3.8-4.2	+16 ÷ -9	+16 ÷ -8
Spring	4.9-5.4	4.1-4.8	-15 ÷ -40	-8 ÷ -35
Summer	6.2-6.6	5.7-5.9	-30 ÷ -50	-27 ÷ -32
Autumn	5.5-5.8	4.8-5.3	-2 ÷ -28	-4 ÷ -25
Annual	5.3-5.7	4.8-5.1	-10 ÷ -27	-8 ÷ -24

The regional climate model used for study under PRECIS is the Hadley Centre model HadRM3P, according to which surface seasonal and annual temperature anomalies over Armenia and the surrounding region (fig.4a) show that entire Armenian region shall have higher temperatures due to global warming.



a) b)

Figure 4: Annual changes of air temperature (^{0}C) (a) and precipitation (%) (b) in 2071-2100 compared with 1961-1990 baseline values, projected by PRECIS

The increase of air temperature shall be maximum in summer season (about 5-9 degrees warmer). There are regional variations within Armenia. West and central region, particularly Ararat Valley shall experience higher warming than rest of the country during all the seasons. Temperature over southern part of Armenia (Suniats highland) shall become mildly warmer. Annual mean surface temperature anomalies for 2071-2100 compared to baseline climatology have essentially same features as the ones described for seasonal mean anomalies. The central and western regions of Armenia shall experience more warming than the rest of the region in the country. Annual temperatures will rise by 4-7 by the end of 21st century (tab.3).

Table 3 Temperature anomalies (^{0}C) compared to 1961-1990 baseline average (PRECIS)

2030

Area	Winter	Spring	Summer	Autumn	Annual
North-east	1.05	1.05	1.23	0.32	**0.87**
Lake Sevan basin	1.4	0.87	1.78	1.78	**1.4**
Shirak	1.05	1.05	1.23	1.05	**1.3**
Aparan Hrazdan	1.6	2.1	0.7	1.4	**1.4**
Ararat Valley	1.05	1.6	0.32	0.7	**0.96**
Vayk	1.05	1.78	1.78	1.05	**1.4**
Syunik	0.32	0.5	1.05	0.7	**0.7**

2070

Area	Winter	Spring	Summer	Autumn	Annual
North-east	2.5	2.5	2.8	1.0	**2.1**
Lake Sevan basin	3.2	2.1	3.9	3.9	**3.2**
Shirak	2.5	2.5	3.2	3.2	**3.0**
Aparan Razdan	3.6	4.6	1.7	3.2	**3.2**
Ararat Valley	2.5	3.6	1.0	1.7	**1.7**
Vayk	2.5	3.9	3.9	2.5	**3.2**
Syunik	1.0	1.4	2.5	1.7	**1.7**

2100

Area	Winter	Spring	Summer	Autumn	Annual
North-east	3-5	3-5	4-5	1-3	**2.5-4.5**
Lake Sevan basin	4-6	2.5-4.5	5-7	5-7	**4-6**
Shirak	3-5	3-5	3-6	4-6	**4-5.5**
Aparan Razdan	4-7	6-8	2-4	4-6	**4-6**
Ararat Valley	2-6	4-7	1-3	2-4	**2.5-5**
Vayk	5-7	5-7	5-7	5-7	**5-7**
Syunik	1-3	2-3	3-5	2-4	**2-4**

Figure 4b shows annual precipitation anomalies over Armenia and the surrounding region. It is seen that entire Armenia shall have a climate shift as far as precipitation is concerned due to global warming. In summer precipitation will reduce over the entire region (tab.4), taking into account the uncertainties of the model to reproduce summer precipitation.

The anomalies of total soil moisture content projected by the model compared to the baseline climatology for the MAM and JJA. As evident of the results, the soil across entire Armenia shall have higher moisture in Spring (MAM) and much drier in Summer (JJA) comparing to the base line. These results agree well with the precipitation projections and the fact that more snow melt during warmer spring. These results indicate that climate change shall have serious implications on cropping pattern and crop yield.

The change of relative humidity by the end of this century compared to the base line climate (1961-1990) indicates that for all the seasons except autumn, the air over the Armenian region shall be drier. In autumn the decrease of humidity will be quite insignificant in the central regions, on the north-east and south even slightly increase of humidity is projected by the model. In spring the air will be drier by 4-8% in the central parts of the country, by 2-4% - in the north-east and south. The maximum reduction of humidity is anticipated in winter and summer (10-14%). Annual relative humidity shall reduce by 5-10% and more.

Table 4 Precipitation anomalies (%) compared to 1961-1990 baseline mean (PRECIS)

2030

Area		**Winter**	**Spring**	**Summer**	**Autumn**	**Annual**
North-east		+7	+2	-9	+7	+3
Lake Sevan basin	East shore	-7	-4	-9	-2	-8
	West shore	+7	+4	-5	+5	+4
Shirak		-11	-11	-7	-4	-8
Aparan-Razdan		-11	-7	-11	-7	-9
Ararat Valley		-13	-9	-13	-9	-11
Vayk		-11	-11	-9	+4	-7
Syunik		+15	+11	+5	+15	+11
Aragats		+11	+11	+2	+13	+9

2070

Area		**Winter**	**Spring**	**Summer**	**Autumn**	**Annual**
North-east		+15	+4	-18	+15	+7
Lake Sevan basin	East shore	-15	-7	-18	-4	-11
	West shore	+15	+11	-11	+11	+6
Shirak		-21	-21	-15	+7	-16
Aparan-Razdan		-21	-15	-21	-15	-18
Ararat Valley		-25	-18	-25	-18	-22
Vayk		-22	-22	-18	+7	-13
Syunik		+29	+22	+11	+29	+22
Aragats		+22	+22	+4	-25	+18

2100

Area		**Winter**	**Spring**	**Summer**	**Autumn**	**Annual**
North-east		+20	+5	-25	+20	+10
Lake Sevan basin	East shore	-20	-10	-25	-5	-15
	West shore	+20	+10	-15	+15	+10
Shirak		-30	-30	-20	-10	-22
Aparan-Razdan		-30	-20	-30	-20	-25
Ararat Valley		-35	-25	-35	-25	-30
Vayk		-30	-30	-25	+10	-18
Syunik		+40	+30	+15	+40	+30
Aragats		+30	+30	+5	+35	+25

3. VULNERABILITY ASSESSMENT OF WATER RESOURCES IN THE CLIMATE CHANGE CONTEXT

3.1. The water resources

From the Armenian highlands, water flows into the Kura River (in Georgia) and Aras River (along the border of Armenia and Turkey) and out to the Caspian Sea (see Figure 5). Armenia's 14 major river basins include nearly 10,000 rivers and streams, only 300 of which are more than 10 km in length; some of these rivers originate from runoff and subterranean springs, while others are fed primarily by melting snow and ice. Lake Sevan – one of the largest high-altitude lakes in the world – along with more than 100 small mountain lakes, stores snowmelt and run-off, spreading river flow from the wet seasons into the dry seasons.

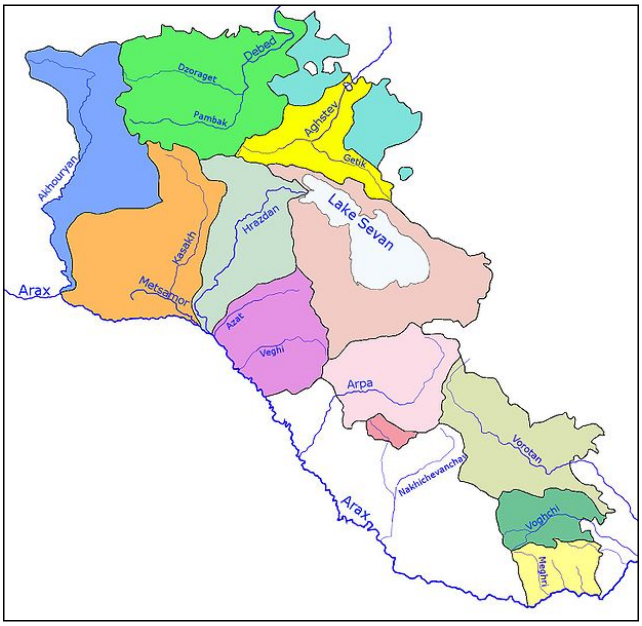


Figure 5: Rivers and lakes of Armenia

For a country with so many important rivers and lakes, Armenia is surprisingly arid with an average annual rainfall of 590mm in the 1960s to 1980s that has shrunk to an annual average of just 530mm over the last ten years. One-fifth of Armenia's land area receives less than 400mm of rainfall each year. In the populous Ararat Valley, average rainfall is just 220mm each year; in contrast, the Aragats highlands average 830mm each year. Most precipitation (on average, 37 percent of the annual total) falls in March, April and May while the least precipitation (17 percent) falls in December, January and February. With such a high degree of variation in altitude, temperature, and precipitation level, Armenia has not one climate, but many: one area of the country may be at risk of drought while another area suffers a flood.

3.2 River flow

Lower precipitation levels combine with higher average temperatures to increase evaporation rates and reduce winter snowpack and spring run-off: As a result less water reaches streams and rivers. Climate change will reduce river flow, lake levels, and, eventually, groundwater reserves. Armenia's total river flow is projected to drop 7 percent by 2030 and 24 percent by 2100 (Table 5).

Table 5. Total projected river flow change

Observation stations (rivers)	**Scenarios**	**Flow Million m^3**	**Change in the flow Million m^3**	**%**	**Period**
Total rivers	Baseline	4994.4	0	0	
		4660.9	-333.5	-6.7	2030
		4269.9	-724.5	-14.5	2070
		3777.6	-1216.8	-24.4	2100

The change in river flows – a loss of one-quarter of total flow by 2100 – varies greatly across Armenia's river basins (see Table 6. below). The Vorotan and Voghji river basins are some of the few river basins that will increase in flow; in these areas, primarily in the Syunik Marz in southern Armenia, the increase in precipitation is projected to outweigh faster rates of evaporation caused by higher temperatures. In most river basins, however, the opposite is expected to take place: rivers flows will decrease as lower precipitation is compounded by the effects of high temperatures. Some of the rivers with the most severe expected decline in river flow are the Marmarik, Martouni, Vedi and Dzknaget, all projected to lose more that three-quarters of river flow by 2100.

Table 6. Projected river flow change in 2100

River-Observation station	Scenarios	Flow	Change in the flow	
		Million m^3	Million m^3	%
Pambak-Toumanyan	Baseline	358		
	T+3.6, 1.01Q	275.5	-82.5	-23.0
Dzoraget – below Gargar	Baseline	477.4		
	T+3.6, 1.01Q	358.4	-119	-24.9
Debed-Ayrum	Baseline	1069.4		
	T+3.6, 1.01Q	842.1	-227.2	-25.1
Aghstev-Ijevan	Baseline	306		
	T+3.6, 1.01Q	218.1	-87.9	-28.7
Getik-Gosh	Baseline	110.7		
	T+3.6,1.01Q	83.8	-26.9	-24.3
Tavush-Berd	Baseline	19.78		
	T+3.6,1.01Q	16.12	-3.66	-18.5
Akhuryan-Haykadzor	Baseline	953.5		
	T+4.4,0.765Q	604	-349.6	-36.7
Hrazdan-Hrazdan	Baseline	248.9		
	T+5.0,0.75Q	159.1	-89.9	-36.1
Marmarik-Aghavnadzor	Baseline	150.4		
	T+5.0,0.75Q	32.8	-117.6	-78.2
Dzknaget – Tsovagyugh	Baseline	34.6		
	T+5.1,1.06Q	8.4	-26.2	-75.6
Masrik-Tsovak	Baseline	105.8		
	T+5.1,0.854Q	73	-32.8	-31.0
Martouni-Geghhovit	Baseline	57.4		
	T+5.1,0.854Q	12.5	-44.9	-78.2
Argichi-Verin Getashen	Baseline	172.9		
	T+5.1,0.854Q	54.6	-118.3	-68.4
All the rivers of the Sevan basin	Baseline	757.7		
	T+5.1,0.954Q	448.6	-309.1	-40.8
Vedi-Urtsadzor	Baseline	52.84		
	T+3.6,0.712Q	12.02	-40.8	-77.2
Arpa-Jermouk	Baseline	167.1		
	T+6.0,0.787Q	56.4	-110.6	-66.2
Meghriget- Meghri	Baseline	92.9		
	T+2.9,1.305Q	90.4	-2.5	-2.7
Voghji-Kapan	Baseline	332.2		
	T+2.9,1.305Q	383.3	51.1	15.4
Vorotan-Vorotan	Baseline	376.8		
	T+2.9,1.305Q	545.5	168.7	44.8
Sevjoor-Taronik	Baseline	466.9		
	T+3.6,0.712Q	369.2	-97.7	-20.9
Metsamor-Taronik	Baseline	466.9		
	T+3.6,0.712Q	369.2	-97.7	-20.9

For a number of Armenia's rivers the greatest cause of reduced flow will be less accumulation of snow and ice, with lower winter precipitation and slightly higher winter temperatures. Snowmelt is responsible for 20 to 40 percent of Armenia's river flow, with most important sources of snow and ice accumulating at 1800 to 2800 meters above sea level. In terms of declining river flow due to reduced snowmelt, Armenia's most vulnerable river basins are the Akhuryan, Arpa, Azat, Hrazdan, and Kasakh.

3.3. Lake levels

Spring snowmelt is the main source of Lake Sevan's chilly alpine waters. The 28 rivers and streams that flow into the lake is expected to decrease 41 percent in flow by 2100; as a consequence, Lake Sevan's water levels will fall over time (see Table 7). In the twentieth century, Lake Sevan's level fell by 19 meters (a 40 percent loss of volume) as the demand for irrigation water and hydro-electric generation grew. In the 1980s a 48 km tunnel was built to bring 250 million m^3 of water each year from the Arpa River to Lake Sevan; in 2004, a second tunnel diverted water from the upper Vorotan River to the Arpa. The Arpa River is projected to decrease a stunning 66 percent in flow by 2100. Without a large-scale investment in the further diversion of water from southern Armenia (where river flows are projected to increase) to Lake Sevan, the decrease in its water levels is likely to be severe. Even large-scale water transfer projects, however, cannot compensate for the losses projected to the Sevan basin in 2100; the projected change in the total volume of water flowing in the Sevan basin, the Arpa and the Vorotan is a loss of 250 million m^3, or 19 percent of current flow.

Table 7: Lake Sevan Basin river flow change

River-Observation station	Scenarios	Flow Million m^3	Change in the flow Million m^3	%	Period
All the rivers of the Sevan basin	Baseline	757.7	0	0	
	T+1.5, 0.983Q	664.7	-92.9	-12.3	2030
	T+3.3, 0.973Q	558.6	-199.1	-26.3	2070
	T+5.1, 0.954Q	448.6	-309.1	-40.8	2100
Arpa-Jermouk	Baseline	167.1	0	0	
	T+1.4,0.923Q	138.1	-29	-17.4	2030
	T+3.2,0.844Q	103.1	-64	-38.3	2070
	T+6.0,0.787Q	56.4	-110.6	-66.2	2100

3.4. Flooding and Mudflows

Many regions of Armenia are prone to floods and mudflows. Given the intensification of anomalities with air temperature and atmospheric precipitation due to climate change, the occurrence of floods and mudflows has also increased in the country during the last decade. Particularly, the damage caused to mudflows in 1994-2007 exceeds 5.6 billion AMD. and the damage caused by flooding for the same period amounts up to 13 billion AMD.

Despite the fact that the analysis shows a long-term reduction of maximum discharges in Armenia's rivers, it is expected that both frequency and intensity of floods and mudflows will increase in the country, which requires implementation of corresponidng adaptation measures, in particularly vulnerable areas.

3.5. Water consumption

Armenia's river and lake water is critically important for irrigation, hydro-electric power generation, and industrial use. Lake Sevan and the Hrazdan River, which connects Lake Sevan to Yerevan and the Aras River, serve the densely populated Ararat Valley and Hrazdan River Basin areas and are of especially vital importance both economically and culturally.

Four-tenths of Armenian water consumed each year is groundwater while six-tenths is taken from rivers and lakes. Nearly ninety percent of all water used in Armenia is used for irrigation or other agricultural purposes (see Table 8); almost all irrigation water is drawn from rivers and lakes, while ninety-six percent of Armenia's drinking water is groundwater. Residential water service, amounting to just 5 percent of all water used each year, is provided by five State water companies.

The overall water volume abstracted by these companies is 590 million m^3, of which an astounding 84 percent is lost as leakages in the water delivery system.

Table 8: Water consumption in Armenia, 2006

	Millions of cubic meters	Share of total water consumed
Households	102	5%
Industry	96	5%
Agriculture	1793	90%
Total	1991	

Armenia’s water infrastructure was built in the Soviet era and efficiency was not a high priority in its design. Forty percent of Armenia’s irrigated lands depend on high-lift pumping stations that use electricity to raise water by as much as 500 meters. Nine percent of Armenia’s electricity consumption is used to pump water for agricultural and residential use. Less than half of all lands requiring irrigation currently receive it; Armenia’s tiny, post-land-reform farms cannot afford the high cost of maintain aging irrigation systems and other related infrastructure.

As the effects of climate change are felt in Armenia from losses to precipitation and river flow, less total water will be available for use by households, farms, and industry. Armenia has an enormous opportunity to avoid water shortages by repairing and maintaining the State-owned water delivery system.

3.6. Health and water quality

Water quality is also an area of great concern as climate change progresses in Armenia. Water-borne diseases like malaria and cholera are already serious health problems in Armenia, and climate change is expected to create more favorable conditions for the reproduction and spread of many diseases. There is no Armenian-specific research available that forecasts the scale of the likely increase in incidence of water-borne diseases with climate change. This is a priority area for future research. Planning for these kinds of serious public health crisis begins with careful epidemiological research, a key adaptation measure for Armenia.

3.7. Social impacts of a water shortage

Over 95 percent of Armenia’s residential water comes from groundwater supplies for which there is no immediate evidence of impending scarcity. No data on Armenia’s groundwater resources has been collected since 1990. Further research is strongly recommended to establish the vulnerability of Armenia’s groundwater reserves to the effects of climate change. In the long-term, however, Armenia’s increasingly scarce surface waters will affect groundwater availability in two ways; as river flow decreases by 24 percent over the next century due to climate change, the recharge of underground reservoirs from surface water will also decrease, while some former users of surface water will switch to groundwater withdrawals. As a result, water shortages may impact on human welfare – demand for groundwater will increase while supplies of surface water, and eventually of groundwater, will decrease. At the same time, demand for all categories of water will be rising with higher temperatures and more rapid evaporation. The health consequences of reduced water supplies for drinking and sanitation have the potential to be very serious.

3.8. Economic impacts of a water shortage

Armenia’s agriculture sector, which accounts for 20 percent of GDP in direct agricultural production and an additional 10 percent of GDP in food manufacturing (945 billion AMD, or US$2.7 billion, in 2007), is highly dependent on irrigation water from rivers, many of which will suffer large-scale reductions in flow as climate change progresses. Half of Armenia’s arable land requires irrigation; with climate change more land will fall under this category but less river water will be available. The actual impact on agricultural production will depend on policy decisions regarding the allocation of irrigation water among farms, and the allocation of all water resources among all uses. These policy decisions will include important choices regarding how much money will be invested in repairing the existing water delivery system to limit leakages.

Crops, which are more vulnerable to drought than pasture and far more likely to require irrigation, represent 14 percent of GDP (430 billion AMD, or US$1.2 billion). A 25 percent reduction in river flow is projected to result in a 15 to 34 percent reduction in the productivity of irrigated cropland, with an average estimated reduction of 24 percent. The expected loss in yield for grapes would be 21 percent and for winter wheat, 25 percent. Total losses to the agricultural sector would amount to 65 to 145 billion AMD, or US$180 to 405 million (with an average impact of 105 billion AMD or US$293 million); this would be a loss of 2 to 5 percent of GDP (3 percent on average).

Depending on policy choices, reductions in agricultural production could also impact on Armenia's food production industry and thereby have a wider-reaching effect on the economy. If agricultural losses result in losses to the food production industry of the same scale – 13 to 34 percent reduction – the additional decrease to GDP would range from 1.5 to 3.4 percent.

3.9. Anticipatory adaptation – preparing for future water shortages

Private measures:

- Households can install small-scale rainwater collection and storage tanks in yards and on rooftops,
- Households, farms and other businesses can implement conservation measures to reduce water use and reuse water where appropriate (for example, the use of non-sewage wastewater in gardens). The development of good conservation practices now will prepare individuals and firms for future shortages.

Public measures:

The state can invest in large-scale infrastructure projects to increase Armenia's capacity for water storage and limit losses from inefficient distribution systems. These investments would include:

- Building dams and reservoirs to increase water storage capacity by 1 to 2 billion cubic meters,
- Upgrading the irrigation water distribution system to reduce losses,
- Extending the existing irrigation water distribution system to cover more arable land (depending on policy choices regarding how scarce water will be allocated across uses),
- Increasing the flow of water to Lake Sevan by transferring water from basins that are predicted to have increased river flow with climate change,
- The state can introduce conservation laws limiting the use of water by households, industry, and farms. These laws could specify the use of particular irrigation techniques or equipment,
- The state can initiate public education programs on conservation and training programs for individuals in water intensive fields like agriculture.

3.10. Reactive adaptation – managing water shortages in real time

Private measures:

- In times of periodic drought or longer-term water shortage, more profound conservation measures may be necessary. Households, farms and other businesses can further limit water use in response to current conditions.

Public measures:

- In periods of water shortage, the state can adopt regulations enforcing tighter restrictions on water use by households, industry and farms. Public information campaigns on conservation measures can accompany these new regulations.

- If water demand exceeds water supply, the state can and must allocate water among different users according to the priorities set by the Water Law of RA including use by households, irrigation, energy production and industry.

3.11. The Millennium Challenge Corporation and water supply adaptation in Armenia

Established by the U.S. government in 2004, the mission of the Millennium Challenge Corporation (MCC) is to reduce poverty in the poorest countries in the world. Countries currently working with the MCC include: Armenia, Benin, Cape Verde, El Salvador, Georgia, Ghana, Honduras, Lesotho, Madagascar, Mali, Mongolia, Morocco, Mozambique, Nicaragua, Tanzania and Vanuatu. MCC also works in partnership with other U.S. agencies, donors and development partners, such as the World Bank, the African Development Bank and the U.S. Trade and Development Agency.

MCC and the Republic of Armenia have signed an agreement to work together to solve irrigation problems and improve the water supply in Armenia, and have planned projects budgeted at US$112 million. These projects fall under two main goals. The first goal is to increase irrigation by 25 percent and improve irrigation efficiency by converting from pump to gravity-fed irrigation. Major projects planned to achieve this goal include: conversion of 15 irrigation systems from pump to gravity; rehabilitation of up to seven reservoirs; rehabilitation of six main canals; renovation and resizing of 68 pumping stations; rehabilitation of the Ararat Valley drainage system; and rehabilitation of tertiary canals.

The second main goal of the projects in which MCC is involved is to transfer financial liability for irrigation management from the Armenian government to water users. Major projects planned to achieve this goal include: strengthening water users associations; clarifying responsibilities for different stakeholders; developing institutional and legal guidelines for farmers’ activities; developing a professional irrigation association; drafting irrigation law; and developing plans to monitor and evaluate project performance.

4. SUMMARY OF PILOT STUDY IN MARMARIK RIVER BASIN

Within the UNDP/GEF “Enabling Activities for the Preparation of Armenia’s Second National Communication to UNFCCC” a pilot study has been implemented to produce a complex assessment of climate change impacts on water resources of Marmarik River Basin of Armenia. Marmarik River Basin was selected as pilot area given the existing various water uses (drinking-household, irrigation, hydropower, recreation) as well as the progress made on river basin planning within the EU National Policy Dialogue in Armenia. In addition there is a long-term series of hydrological data in the basin, and the basin itself is characteristic for Armenia given its natural-climatic conditions.

4.1. Hydrological characteristics and water quality

Marmarik River Basin is located in the northern part of Kotayq marz of Armenia. It is locked in intermountain depression between Tsaghkunyats and Pambak mountains; the depression’s average altitude is 2300 m above sea level. The basin’s relief is typical mountainous with very fractioned valleys and gorges. This catchment basin is dominated with impervious rocks. About 12 per cent (50 sq.km) of the basin’s area is covered with forest where big-anther oak and Caucasian hornbeam dominates.

Figure 6: Location of Marmarik Basin in Armenia

Marmarik River is the biggest tributary to Hrazdan River. The river’s length is 37 km and its catchment basin’s area is 427 sq.km. The river head locates in Tsaghkunyats mountain chain at an altitude of 2520 m above sea level. The river’s tributaries are Gomur, Erkarget and Ulashik rivers. Marmarik River feeds on melting snow (55%), rain (18%) and underground waters (27%).

Hydrological observations in Marmarik River basin are performed since 1930 by “ArmStateHydroMet” SNCO. Total number of hydrological observation points is 6 with 3 closed in different years.

Quality of water in Marmarik River is monitored since 1986 by “Environmental Effect Monitoring Center” SNCO. At present, samples for checking water quality are taken at 2 points: at the River’s head and at its estuary. Current studies of the water’s quality show that waters of Marmarik River are medium hard. Concentration of dredge particles is low and does not exceed the allowed limits. No essential changes are registered according to the water quality from the River’s head to its estuary. Oxygen regime of the River was within the defined norms in the last 20 years. Organic pollutants level in the River’s waters is low while the River is of high self-purification potential. Values of almost all hydro-chemical indicators (except for V, Mn and Al) are within ambient water standards for norms for fishery enterprises. However, given the project decrease of water quantity due to climate change, it is expected that the quality of water in the basin will deteriorate.

4.2. Water use in Marmarik River basin

Waters of Marmarik River basin are mainly used for irrigation, hydro energy, municipal, and industrial purposes.

As of 2007, annually about 3.4 million m^3 water is drawn from Marmarik River basin for irrigation, 3,6 million m^3 for drinking-household, 4,7 million m^3 for industrial purposes and 38.4 million m^3 for hydro energy purposes.

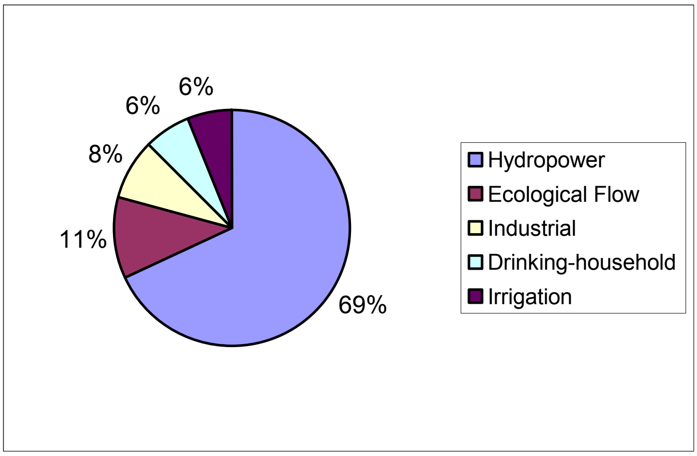


Figure 7: Percentage distribution of used water resources

In fact, annual amount of water intake in Marmarik River basin for general purposes makes about 32.3 per cents of the River's annual flow, while the rest is in free flow, 111 million m^3 per annum, and ecological flow, 6.3 million m^3 (Figure 7).

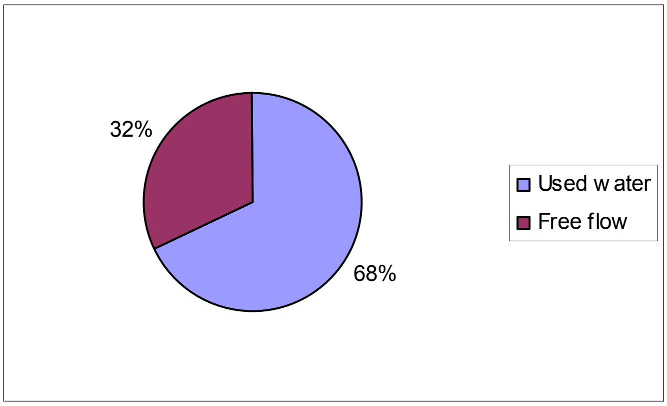


Figure 8: Overall annual water abstraction from Marmarik River Basin

4.3. Assessment of changes in meteorological elements

Changes (%) in average annual air temperature in Marmarik River basin in 1991-2007 compared to the baseline, 1961-1990, grew by 0.5^{0}C (over 9%) and multi-year average value reached 6.0^{0}C:

Table 9: Average air temperature (^0C) changes in Marmarik River basin in 1991-2007 as compared to baseline (1961-1990), by seasons and annually

Time period	Winter		Spring		Summer		Autumn		Annual	
	F	Δ	F	Δ	F	Δ	F	Δ	F	Δ
1961-1990	**-6.0**	0.4	**4.8**	0.3	**15.9**	0.7	**7.3**	0.5	**5.5**	0.5
1991-2007	**-5.6**		**5.1**		**16.6**		**7.8**		**6.0**	

F - multiyear average value, Δ - difference

Total precipitation in 1991-2007 compared to baseline period, 1961-1990, showed average annual growth by 18 mm (2.6%) and reached 711 mm.

4.4. Assessment of changes in hydrological regime of Marmarik River basin

To assess changes in actual river flow in Marmarik River basin in 1991-2007, multiyear observation data on river flows collected in Marmarik-Aghavnadzor, Marmarik-Hankavan and Gomur-Meghradzor hydrological observation points were used.

Table 10: Changes in actual river flow in Marmarik River basin in 1991-2007, compared to the baseline (1961-1990)

River-Observation point	Year/Season	Anomalies of river flow	
		million m^3	%
Marmarik-Aghavnadzor	**Year**	**-3.682**	**-2.35**
	I-III	-0.65	-5.67
	IV-VI	-1.93	-1.64
	VII-IX	-0.15	-0.86
	X-XII	-0.18	-1.73
Marmarik-Hankavan	**Year**	**0.38**	**0.70**
Gomur-Meghradzor	**Year**	**-0.80**	**-1.77**

In its formation area and in its upstream, Marmarik River's flow almost is not affected by anthropogenic impact (human economic activity) and thus the flow may be considered natural. The analysis shows, that, according to data collected at Hanqavan hydrological observations point, Marmarik River upstream flow is almost unchanged in 1991-2007 compared to the baseline; in the rest of the stream, decrease in river flow is registered.

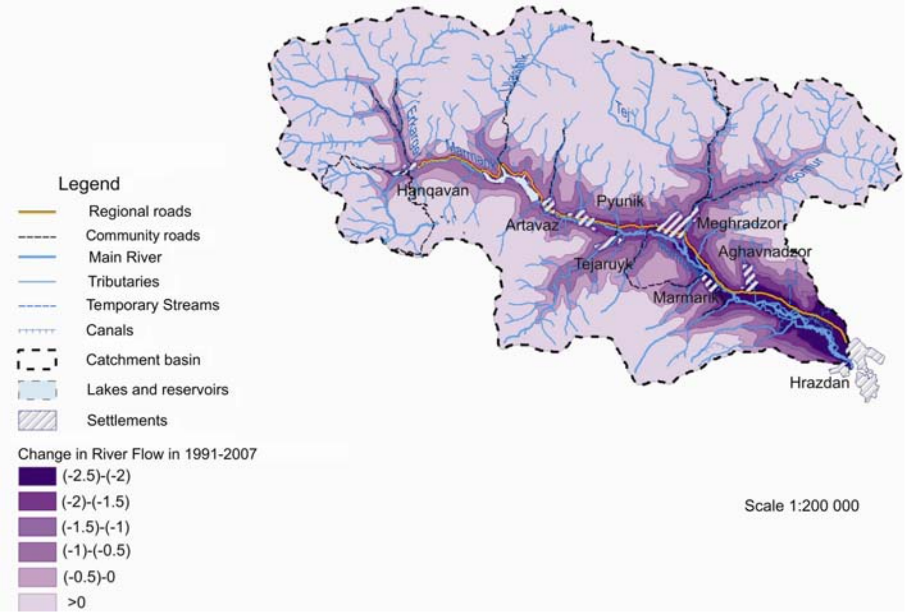


Figure 9: Map of changes (%) in actual water flow in Marmarik River in 1991-2007

4.5. Assessment of climate change impact on water resources in Marmarik River basin for 2030, 2070 and 2100

To assess vulnerability of Marmarik River basin water resources: data on the actual water resources and use patterns, climate forecasts according to the application of PRECIS software based on Hadley Centre regional model under IPCC A2 emissions scenario, statistical or regression analysis, and model created with ArcGIS software application were used. Via above mentioned model the Marmarik River basin water resources vulnerability to climate change was analyzed, assessed and mapped for 2030, 2070 and 2100 (see Table 11 and Figure 10).

Table 11: Assessment of annual water flow vulnerability in Marmarik river basin for 2030, 2070 and 2100

River-Observation point	Scenarios	Flow, million m^3	Change in flow		Timelines
			million m^3	%	
Marmarik-Aghavnadzor	Baseline*	152.05			
	T+1.4, 0.91Q	117.87	-34.18	-22.5	2030
	T+3.2, 0.82Q	77.65	-74.40	-48.9	2070
	T+5.0, 0.75Q	40.35	-113.70	-73.5	2100
Marmarik-Hankavan	Baseline*	53.43			
	T+1.4, 0.91Q	44.94	-8.49	-15.9	2030
	T+3.2, 0.82Q	34.88	-18.54	-34.7	2070
	T+5.0, 0.75Q	25.51	-27.92	-52.3	2100
Gomur-Meghradzor	Baseline*	49.12			
	T+1.4, 0.91Q	39.64	-9.48	-19.3	2030
	T+3.2, 0.82Q	28.94	-20.18	-41.1	2070
	T+5.0, 0.75Q	19.39	-29.73	-60.5	2100

*1961-1990

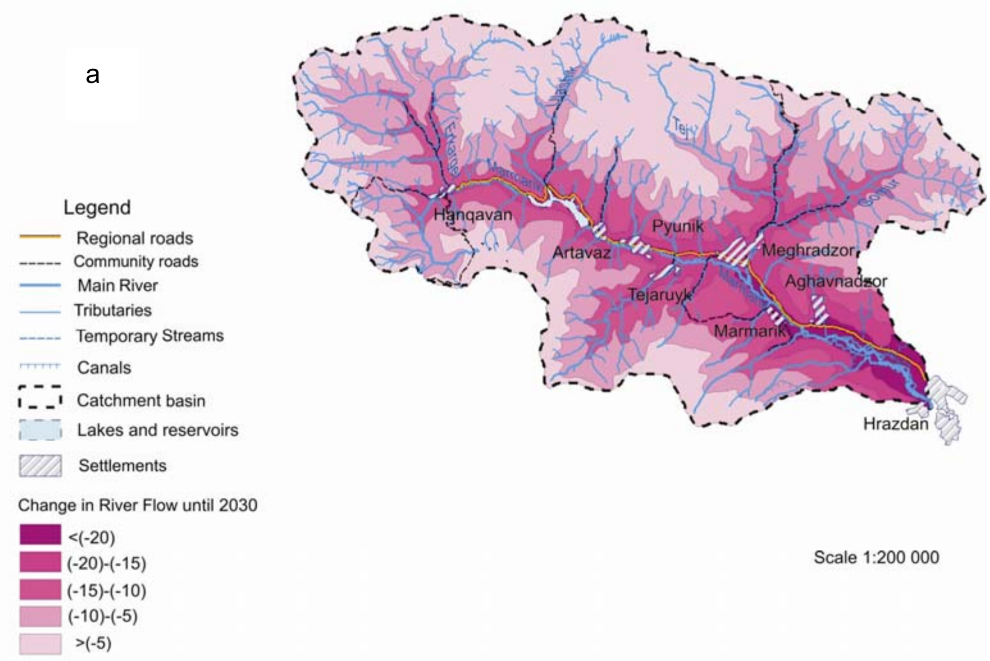


Figure 10a. Forecasted change in actual river flow in Marmarik River basin for a) 2030, b) 2070 and c) 2100, in per cents, under IPCC A2 scenario.

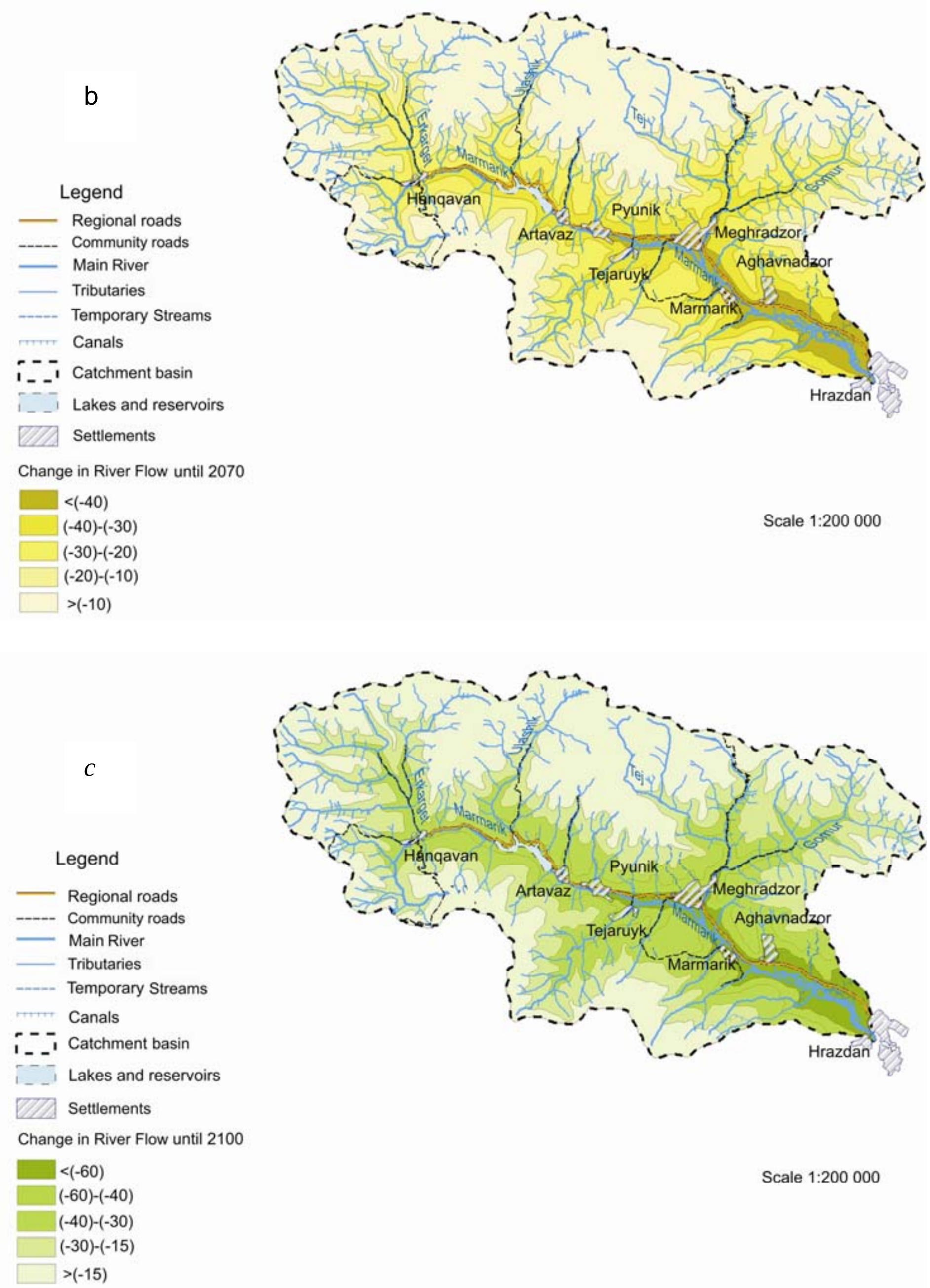


Figure 10b and c. Forecasted change in actual river flow in Marmarik River basin for a) 2030, b) 2070 and c) 2100, in per cents, under IPCC A2 scenario.

Taking into account baseline (1961-1990) amounts of snow precipitation, projections of expected change in those in Marmarik River basin were made for 2030, 2070 and 2100. Thus, according to estimation scenarios, decrease was projected for the basin as follows: 7 per cent (24 mm) in 2030, 21 per cent (45 mm) in 2070 and 30 per cent (64 mm) in 2100.

4.6. Changes in water balance and water economic balance

Assessment of changes in Marmarik River basin according to the climate change scenarios for 2030, 2070 and 2100 shows decrease in amount of precipitation by 176 mm or 24.5 per cents, and by 282 mm or 73.5 per cents – in river flow. Due to air temperature increase, evaporation will rise by 106 mm or 31.8% (fig. 11).

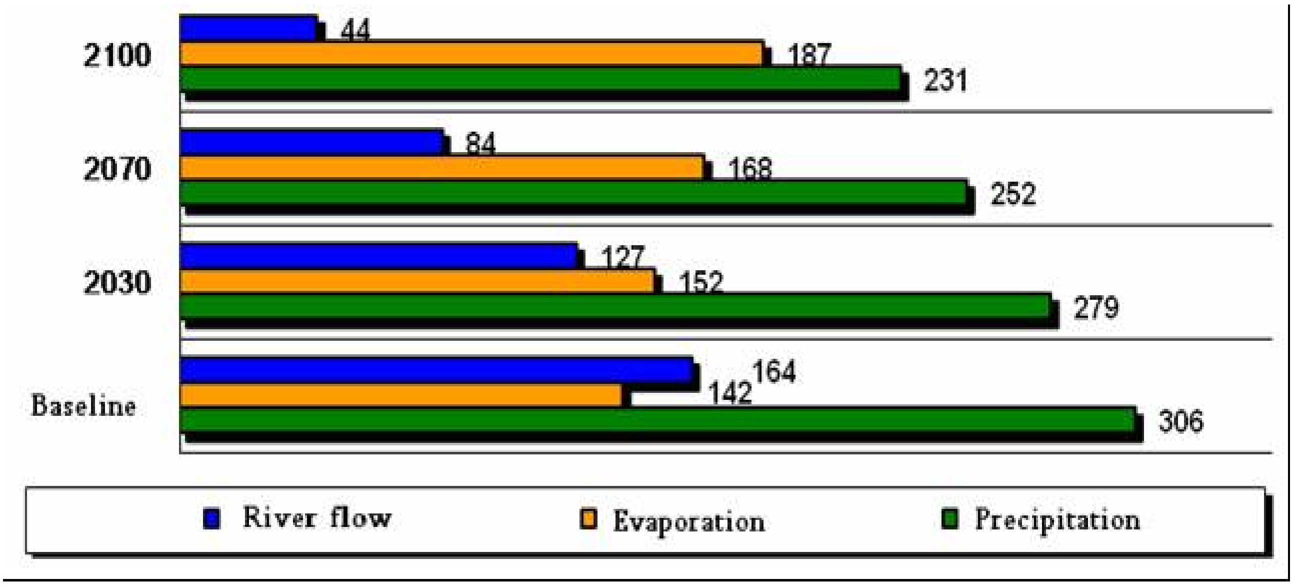


Figure 11: Water balance in Marmarik River basin at the River's estuary according to climate change scenarios for 2030, 2070 and 2100 (million m^3)

Table 12: Water industry balance in Marmarik River basin, at the River's estuary, million m^3

Inflow (years)							Outflow (years)			
Elements of inflow/outflow		2007	2030	2070	2100		2007	2030	2070	2100
Return flows	River inflow	164	123.9	81.7	42.4		--	--	--	--
	Water supply to settlements	1.05	2.60	2.80	3.30		2.10	3.47	3.80	4.40
	Water supply to rest sites	0.01	0.03	0.04	0.06		0.02	0.04	0.06	0.08
	Irrigation	0.84	1.01	-	-		3.35	5.07	4.34	4.05
	Animal pond	0	0.01	0.01	0.02		0.04	0.06	0.08	0.10
	Gold mine of Meghradzor	0.28	0.43	0.55	0.80		0.29	0.45	0.60	0.90
	Small HPPs	30.0	40.0	40.0	40.0		30.0	40.0	40.0	40.0
	Hrazdan TPP	0.26	0.26	0.26	0.26		8.37	8.37	8.37	8.37
	"Mika" cement	1.69	4.22	4.22	4.22		2.41	6.02	6.02	6.02
Total		198.13	172.46	129.58	91.06		46.58	63.48	63.27	63.92
Difference between inflow and outflow		*151.6*	*109.9*	*66.3*	*27.1*					

At the same time, due to increase in population, use of recreation resources, irrigated lands and industries demand for water in the basin will grow from 46.6 million m^3 to 64 million m^3 while supply will decrease from 198 million m^3 to 91 million m^3 in 2100. As a result, difference between water supply and water demand will reach 27 million m^3 annually (table 4), that will make water shortage more severe in summer period.

4.7. Economic consequences of climate change impact on water resources in Marmarik River basin

At present waters of Marmarik River are mainly used for municipal and sanitary purposes as well as for irrigation, recreation and industries, including electricity generation at Hrazdan TPP and cement production at "Mika-Cement" CJSC.

However we must stress that Marmarik River waters' use is not efficient, because the flow is not regulated and water users cannot enhance production capacity of the irrigated lands. This issue will be partially sold after the start up of the Marmarik reservoir exploitation that is envisaged soon. According to design estimations, the reservoir's useful capacity will be 23.0 million m^3; this amount of water will allow increasing irrigated lands area by 940 ha in Meghradzor, Aghavnadzor, Marmarik and Pyunik villages.

Natural and climatic conditions of Marmarik River basin allow cultivating a limited number of crops: wheat, late-ripening potato, vegetables in small quantities (e.g. cabbage) and forage crops. Among perennial plantings, fruit-trees are common, including seminal and drupaceous trees.

Mining and tourism are not of crucial importance for water resources at present, taking into consideration their low development potential. Although “Mika-Cement” CJSC that uses Marmarik Rivers’ waters will in perspective increase its production and thus water use 2.5 times, its influence on water resources is not crucial either. Small HPPs do not create problems because they return the used water in full, however the output of that plants will be affected. In Marmarik River basin, small HPPs (Hanqavan, Tezh Get) are being constructed as they are presumed to be of a certain development perspective. Further, we must take into account that norms of minimal ecologic flow are under revision at present.

As for Hrazdan TPP, where exploitation of a new 5th block is planned (one condensate aggregate of 300 MW and one gas-turbine aggregate of 160 MW power), its water supply is envisaged to be provided from Hrazdan River.

4.8. Assessment of financial and economical losses of water users and water sector due to climate change impacts

As agriculture is the most sensitive sector in water supply vulnerability aspect, the relevant estimations of economic impact of climate change were performed using crop productivity, cattle breeding productivity and those products’ marker prices. The results received may be used as a basis for population food security norms estimation. Current estimations show that crops productivity and aggregate product vulnerability in Marmarik River basin’s irrigated lands amounted to 346.0 million AMD in 1991-2007. For mid-term, that is, for the consequent 20-25 years, vulnerability will amount to 797 million AMD. Crops productivity and aggregate product vulnerability for communities using Marmarik River basin’s irrigated lands are provided in market prices both for current and mid-term period (for consequent 20-25 years).

4.9. Proposed adaptation measures

The proposed adaptation measures in Marmarik River basin include several directions. They relate to accurate assessment and systematic observation of water resources, legal and institutional measures, as well as technical measures directed towards reduction of water losses, rational use and storage.

4.9.1. Assessment of water resources

The gauging equipment of the curreently operational 3 hydrological observation posts in Marmarik River basin are outdated, which impacts on the quality of observed data. It is necessary to upgrade the hydrological posts with contemporary equipment (preferable with automated gauging devices) in order to increase the reliability of data and improve the data management process.

Currently in the Republic of Armenia, including Marmarik River Basin, no proper measurement and monitoring of snow cover, water content in the snow and the rate of snow melt is being conducted, which is extremely important information for hydro-meteorological forecasts. It is proposed to re-initiate such measurements and monitoring.

As for groundwater resources, both in Armenia and Marmarik River basin, no monitoring is being conducted since 1993. Currently archive data is being used for groundwater resources which do not reflect the changes occurred during the last 15 years, including the ones within the climate change context. It is necessary to conduct research on groundwater and revitalize monitoring network to get new, up to date data, as well as assess the changes in groundwater resources due to climate change.

And, finally, while transferring the actual river flow into natural flow methodology from former Soviet times has been used, and thus the figures of return waters are approximate. It is suggested to conduct detailed studies on calculation of natural flow using the contemporary methodologies, which will enable calculation of the water return after use for drinking-household, irrigation and industrial purposes more accurately.

4.9.2. Legal-Regulatory measures

Taking into consideration the vulnerability of water resources in Marmarik River Basin due to climate change, it is necessary to implement several legal-regulatory measures for fostering adaptation. Particularly, it is suggested to implement the following measures:

- Develop regulation for considering the climate change factor while assessing the long-term demand for water resources;
- Make the status of “Marmarik Hydrological Reserve” consistent with the requirements of the provisions of the Republic of Armenia Law on Nature Protected Areas, including definitation of protection level and approaches;
- Develop economic and administrative incentives for reduction of water losses from water supply and irrigation systems;
- Identify legal measures for promoting introduction of water saving technologies (e.g. drip irrigation);
- Develop corresponding legal acts for determination of priority water use directions in river basin plans.

4.9.3. Institutional measures

The institutional capacities of agencies involved in surface and groundwater resources monioring, management, water use permits and compliance assurances are not satisfactory. Despite the trainings implemented with the assistance of international organizations during the recent years, there is still need for additional trainings for the specialists of above mentioned agencies and revision of the wages as low salarieis of corresponding specialists contain risks in terms of quality of work. In this regards large-scale institutional strengthening measures are required including strengthening of the Water Users Associations’ capacity.

4.9.4. Technical measures

- Construction of reservoirs to regulate the water flow,
- Reduction of water loss from irrigation and drinking-household sectors through rehabilitation of the systems and renovation of pipelines,
- Moisture (water) accumulation in irrigated fields via keeping snow or snowmelt waters,
- Deepening watering furrows for moisture accumulation and using polyethylene cover for cultivated crops’ sowing in early spring
- Shift from relatively high water demand crops to more drought-resistant crops,
- Application of state of art agri-technical measures and irrigation technologies (e.g. drip-subsoil, squirt-basin, micro-sprinkling, subsurface: porous tubes or mole’s).

Besides, the long lasting adaptation measures may also include reforestation and afforestation of the Maramrik river catchment area to regulate the surface flow and water saving capacity.

4.10. Significance of considering the climate change impacts in long term water resources management planning

The work performed allows making suggestions and conclusions of a more general nature on more comprehensive frames of mitigating the climate change’s negative impacts on river basins and water use spatial systems:

- Vulnerability of water resources should be estimated based both on average annual climatic conditions and conditions in years with different supply of resources (e.g. low-water years, projections etc.) as well as seasonal resource distribution;
- Climate change impact on water use sectors should be estimated applying both water resources vulnerability and water deficit due to climate change in the basin based on water industry balances;
- Selection of area under assessment of climate change impacts (river basin or other big area) should inherit opportunity to compile compatible and comparable water and water industry balances
- In planning climate change adaptation measures as well as distribution of water resources in the periods of deficit, it is necessary to take into consideration water use priorities set forth by the RA legislation;
- Climate change adaptation measures should be planned considering water resources vulnerability, as well as economic feasibility of the measures proposed;
- Climate change impact assessment on water use has to consider the water resource vulnerability in conjunction with climate change immediate impact on the sector itself,
- Climate change induced economic losses have to be assessed considering the quantitative vulnerability of water resources (deficit), and immediate and mediated impact on water quality;

Planning and implementation of climate change adaptation measures shall be performed applying the complex approach to the selected river basin(s) or even for the country as a whole considering the national water policy, strategy, legislation and sustainable economic development priorities

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