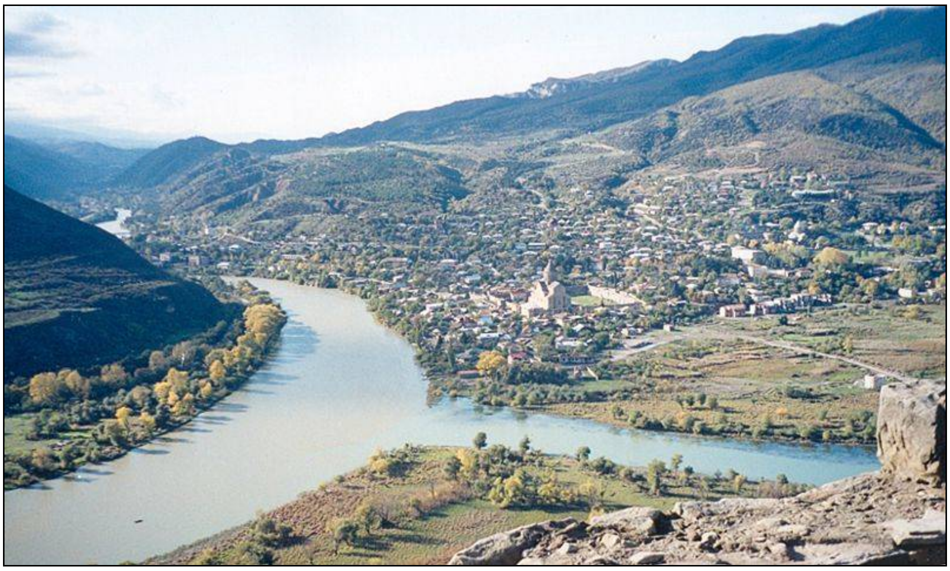
Adaptation to Climate Change in the Kura-Aras River Basin



River Basin Snapshot

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Stefan Zeeb

Head of Division
Competence Center Water and Waste Management

Content

Executive Summary

The Kura-Aras River Basin Snapshot: assessing the needs for adaptation to climate change in the South Caucasus. This basin snapshot aims at assessing historical trends and future projections in the context of climate change compared to other impacts on the water balance in the basin. It also evaluates strategies by national governments and donors for climate change adaptation and identifies critical obstacles to these strategies. Finally, it assesses the scope for no regret measures and possible new measures for climate change adaptation. Although the river basin is shared by five countries, the snapshot concentrates on the South Caucasus states Armenia, Azerbaijan and Georgia, which largely depend on water from the basin. This snapshot is part of a series of basin snapshots in developing countries edited by KfW on behalf of the German Ministry of Economic Cooperation and Development (BMZ).

The river basin is characterized by diverse climatic and hydrological conditions. With a surface area of about 188,000 km², the basin of the two rivers is little larger than the Rhine River basin. Both rivers originate in the northeast of Turkey and both are a little longer than the Rhine River. The Kura has a length of 1,364 km and flows through Georgia and Azerbaijan into the Caspian Sea. Some of its tributaries originate in the mountains of the Greater Caucasus and are largely fed by seasonal and constant snow melt. The Aras River has a length of 1,264 km and forms the boundary between Turkey and Iran to the south and Armenia and Azerbaijan to the north. Then, it flows north and joins the Kura short before its outlet into the Caspian Sea. Shortly after the confluence with the Aras, the Kura has an average flow of about 17.3 km³ per year (average 1930-1984), which is about a quarter of the average Rhine River discharge. Precipitation in the river basin generally increases with elevation. Desertification is advancing particularly in some parts of east Armenia and Azerbaijan. Due to the diverse climatic conditions in the basin, a high variety of natural ecosystems can be found. The population of the basin is at about 14 million inhabitants.

A lack of cooperation among the countries complicates transboundary water resources management. The South Caucasus region is home to numerous scattered ethnic groups, religions and cultures. Bilateral conflicts between Armenia, Azerbaijan and Georgia started soon after they gained independence. These conflicts hamper a transboundary river management which would provide the basis for further research on the hydrological regime in the basin and a joint water resources management. Armenia and Azerbaijan both adopted a bilateral agreement with Iran from Soviet times on joint utilization of water resources. Several donors support joint river management through the exchange of data on water quality and quantity. Improved cooperation among the South Caucasus states is the objective of the Caucasus Initiative of the BMZ launched in 2001. First steps towards cooperation have been initiated.

Agriculture uses about two thirds of the water in the South Caucasus Both rivers have been regulated by dams. The largest has been built at Mingechevir, where the reservoir has a storage capacity of 15.7 km³, almost the yearly flow of the Kura after the confluence with the Aras. The dams are used for hydropower and irrigation and contribute to regulate the river flow. In all three South Caucasus states, 60-70% of the water is used for agricultural purposes, even though the contribution of the sector to the GDP (including rainfed agriculture) ranges from only 6% in Azerbaijan to 19% in Georgia.

Historical hydrologic data are incomplete. However, the impact of climate change is visible. Hydrological data were recorded during Soviet times, but many of these records were stopped after 1990. Even the existing data are difficult to access and their quality is partly doubtful. According to available data, in Salyan about 100 km from the outlet of the Kura into the Caspian Sea, the average discharge has declined by about 15% from the 1930s to the early 1980s. However, the interannual variations are strong. Rising temperatures and consequent snow and ice melting are obvious, since rivers fed by snow show an increasing discharge. Other rivers show a strong reduction in discharge which might be caused by increasing water withdrawal. The Caspian Sea level increased by about 2.5 meters since the 1970s, following a reduction of 3 meters since the 1920s.

Climate and human interferences cause strong river flow variability. Strong variability in river discharge is not a new phenomenon. Both rivers have experienced floods at least since data were recorded, caused by snow and ice melt and intense precipitation in spring and summer and intensified through anthropogenic interferences in the natural river flow, for instance through settling of flood plains or lining of river courses. On the other hand, river flows are low during autumn and winter. Together with increasing water use, this leads to water scarcity and water quality degradation, in particular in the east of the basin.

Water quality in both rivers is threatened by various sources. Even though there is a lack of well founded data on surface and in particular on ground water, water quality is an important challenge even without climate change. Since Soviet times, water has been polluted through agricultural activities and chemical industry. Moreover, mining activities led to heavy metal contamination and untreated domestic wastewater adds organic pollution. There is a lack of wastewater treatment plants and those which exist often do not work properly. Climate change has the potential to further threaten water quality in both rivers.

Azerbaijan is particularly vulnerable. As the country which is situated most downstream, Azerbaijan depends on its upstream neighbors. More than three quarters of Azerbaijan's renewable water resources are generated outside of the country. The Kura and Aras Rivers provide about half of the drinking water and 60% of the irrigation water in Azerbaijan. Together with Armenia, the country is particularly vulnerable to droughts, since semi arid and arid areas are advancing. Moreover, the country is threatened by a varying level of the Caspian Sea. Given this background, it becomes clear why Azerbaijan signed and ratified the UN convention on the Protection and Use of Transboundary Water Courses and International Lakes, while Armenia and Georgia did not.

Future projections indicate more extreme weather events and continuing ice and snow melting. The Intergovernmental Panel on Climate Change (IPCC) relies in its reports on several of the most commonly used General Circulation Models (GCMs), comparing projections for temperature and hydrological variables for the period 2030-2049 to historical figures of the period 1980-1999. An analysis of seven locations in the Kura-Aras River Basin using the World Bank's climate change data tool shows that most projections by the models are relatively consistent concerning the following:

- *Air temperatures* will most likely increase.
- *Precipitation variability*: Precipitation is likely to happen less regularly but more intensely.
- *Average annual precipitation* is projected to decrease except for the eastern part of the river basin (Azerbaijan), where the models do not agree.

Concerning *runoff* (precipitation minus evapotranspiration), the future development is not clear. The tool does not project changes in river discharge, but the projections on rainfall happening less regularly but more intensely indicate an increased risk of floods and droughts. Melting snow and ice will most likely increase regular discharge during summer. Once the glaciers disappear completely (estimates suggest that hardly any glaciers might be left by 2100), the hydrology will lose one of its main drivers and regulators. In areas where total average discharge decreases, this will contribute to water quality degradation, since less water has less potential to dilute pollutants. Concerning the level of the Caspian Sea, projections are inconsistent.

Governments and donors support development and adaptation. Being signatories of the UN Framework Convention on Climate Change (UNFCCC), Azerbaijan issued its first national communication to the convention in 2000, while Georgia and Armenia completed their second national communications in 2009 and 2010, respectively. Azerbaijan estimates that the anticipated adaptation measures will cost about USD 3.2 billion, out of which about USD 750 million are earmarked for projects related to water resources. The costs for the projects proposed by Armenia and Georgia are not clear. Implementation of the measures in the communications has been sketchy. Water related projects of mainly multilateral donors concentrate on improving cooperation among the South Caucasus states. GIZ is currently active in a project on protecting biodiversity in the three countries.

Through KfW, German Financial Cooperation contributes with individual infrastructure projects. Through KfW Entwicklungsbank (Development Bank), German Financial Cooperation is currently active in water and wastewater infrastructure projects in Armenia, Azerbaijan and Georgia. The activities include the rehabilitation and construction of water and wastewater networks, which is one approach to adapt to water scarcity and water quality degradation. In addition, KfW is implementing different projects with the objective to protect biodiversity in the three South Caucasus states, increasing the ecosystems' resilience to climate change.

Recommendations: no and low regret measures targeting floods and droughts. Based on the most important impacts of climate change, adaptation measures can be classified into no regrets, low regrets and climate justified measures. Adaptation measures targeting drought and water quality issues are no regret measures, since even without climate change water availability and quality will most likely decrease. Those which tackle floods are low regrets, since climate change will most probably increase the intensity of floods.

Concerning the Caspian Sea level, future developments are more questionable. Records show that the level decreased for decades before rising again since the 1970s. It is not clear how the future water level will develop, regardless of climate change. Given that uncertainty, it is not advised to target a rising or falling Caspian Sea level through adaptation measures. For all categories, there is a wide range of adaptation measures, including among others infrastructure projects, awareness raising and improved land use policies.

Note: Title picture: Confluence of the Aragvi and Kura rivers, Mtskheta, Georgia, October 2000; source: Wikimedia Commons (2007a)

Part one: Water resources and Climate

Background

The Kura-Aras (the latter is also spelled Araks or Arax) River Basin is a transboundary river basin located in the South Caucasus. This basin snapshot concentrates on the countries Armenia, Azerbaijan and Georgia, although the part of the basin located in Turkey and Iran is not negligible. This chapter gives a short overview on the two rivers, their basin and main characteristics. The chapter concentrates on surface water, since there is very little knowledge on groundwater resources.[1]

Geography

The Kura-Aras River Basin covers part of the countries Azerbaijan, Georgia, Iran and Turkey and the entire area of Armenia. The basin of the two rivers has a total size of about 188,000 km². Table 1 shows the distribution of the basin among countries and the share of the respective country area covered by the basin.[2]

Country	***Share of river basin area in country***	***Share of country covered by basin area***	***Population in the basin (in million)***	***Population growth(2009 est.)***
Armenia	15.8%	100.0%	3.2 (2003)	- 0.03%
Azerbaijan	29.2%	63.6%	4.8 (2003)	+ 0.76%
Georgia	19.3%	52.2%	2.7 (2003)	- 0.33%
Turkey	15.3%	3.7%	N.A.	+ 0.88%
Iran	20.3%	2.3%	2.4 (2000)	+ 1.31%

Table 1: The countries in relation to the river basin; source: UNDP 2007, p. 7, 17

The Kura River has a total length of 1,364 km. Its source is located in the Anatolian highland in the northeast of Turkey at a height of 2,700 m. It flows through Georgia and Azerbaijan into the Caspian Sea. The Kura is fed by seasonal snowmelt (36%), groundwater (30%), rain (20%) and constant ice and snow melt water from glaciers (14%).[3] The largest tributary of the Kura, the Aras River, is 1,264 km long. It also originates in East Turkey and forms the border between Turkey and Armenia, Iran and Armenia and Iran and Azerbaijan. Then, it flows into Azerbaijan and joins the Kura.[4] A map of the rivers and their basin is shown in figure 1.

[1] UNDP 2007, p. 59
[2] UNDP 2007, p. 7
[3] ADB 2008, p. 3-12
[4] UNDP 2007, p. 7

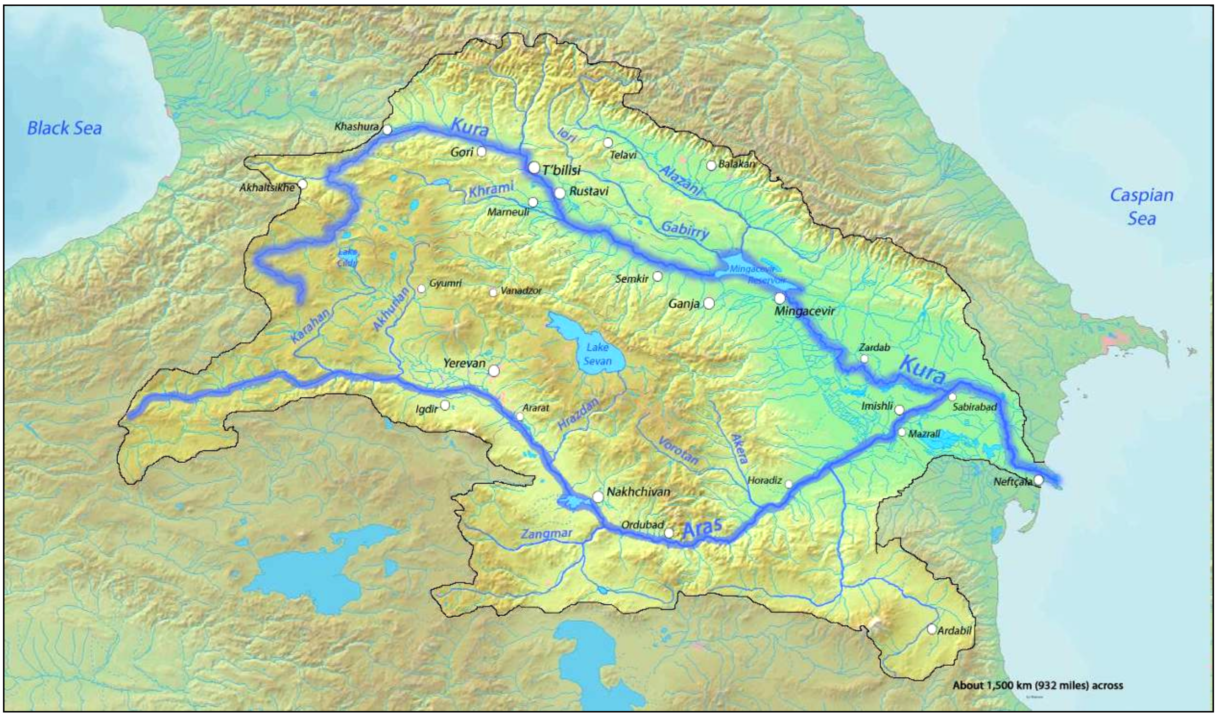

Figure 1. Map of the Kura-Aras River Basin; source: based on Wikimedia Commons 2010

Climate and Hydrology

The river basin covers areas with unequal climatic conditions, threatened by both floods and droughts. In the basin areas in Turkey and Iran, the climate is dry. In Armenia, summers are usually hot and dry and winters are cold and wet with large local deviations. Azerbaijan and Georgia both have Alpine climate in some areas and dry steppe climate in others.[5] In the river basin, the annual precipitation ranges from less than 300 mm per year in Nakhichevan (Azerbaijan) to more than 1,500 mm per year in Krestoviy Pereval (Georgia). Similarly, the average annual air temperature ranges from -0.2°C in Krestoviy Pereval (Georgia) to 14.5°C in Salyan (Azerbaijan).[6] A map showing the climate zones of the Caucasus Ecoregion is shown in annex 1.

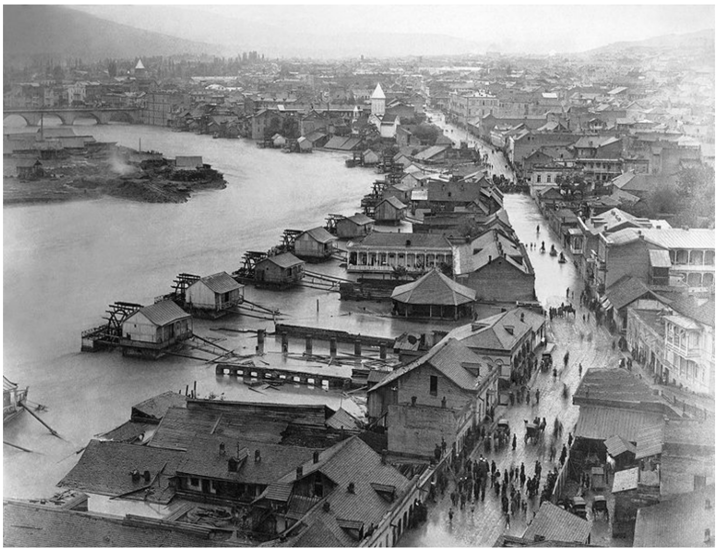
Figure 2. Flooding in Tbilisi in 1893; source: Wikimedia commons 2007

The water flow of the rivers varies significantly during the year. In general, snow and ice melt result in spring floods during spring and summer, while the flow is lower in autumn and winter.[7] Annual precipitation generally increases together with elevation until 2,000 m and decreases from the west to the east. Rivers which originate in the

[5] UNDP 2007, p. 12
[6] UNDP 2007, p. 11
[7] UNDP 2007, p. 9

high mountains in the Greater Caucasus are characterized by high flood periods, starting in spring when snow and ice start to melt and lasting for about six months. Rivers with a source located in the foothills often experience two floods per year; the first one in spring due to snow melt and the second in fall following downpours. Most of the floods happen regularly. From time to time however, sudden intensive snow melting causes devastating spontaneous floodings.[8]

Droughts are threatening in particular the Eastern part of the region, with the lowest precipitation rates in the Terek-Kuma and Kura-Aras lowlands and the Ararat Valley with disastrous impacts on agriculture. Desertification is advancing in these areas.[9]

Water storage

Dams and reservoirs have been constructed in the basin with the objectives to reduce flood risks, generate hydropower and withdraw water for irrigation. Hydropower accounted for 32% of Armenia's electricity production in 2006.[10] In Azerbaijan alone, 62 water reservoirs with a capacity of more than one MCM (million cubic meter) each were built. However, not all of them are located at rivers, with some collecting rainwater only. Five dams in the Kura-Aras Basin are used to generate electricity. Among them, the dam at Mingachevir stands out due to its unique size. Built in 1953, the reservoir has a size of about 15,730 MCM and a surface area of 605 km².[11]

In 1971, a dam was completed at a location of the Aras which today forms the border between Iran and Nakhichevan, an Azerbaijani exclave in Armenia. Hydropower and irrigation water are shared equally between Iran and Azerbaijan under a joint river management policy agreed between Iran and the Soviet Union in 1957. Table 2 shows the main characteristics of all hydropower plants in Azerbaijan and the Aras dam.

Name	***Built in***	***River Basin***	***Country***	***Location***	***Capacity (in MCM)***	***Surface area (in km²)***	***Dam height (in m)***
Varvara	1952	Kura	Azerbaijan	Yevlakh	62	21.4	12
Mingachevir	1953	Kura	Azerbaijan	Mingachevir	15,730	605	80
Aras	1971	Aras	Azerbaijan/Iran	Nakhchivan	1,350	145	40
Shamkir	1983	Kura	Azerbaijan	Shamkir	2,677	115	70
Yenikand	2000	Kura	Azerbaijan	Shamkir	158	22.61	24

Table 2. Characteristics of hydropower generating dams; source: Mammadov, p. 8

The high sediment load of the rivers fills the reservoirs and reduces their capacity. For instance, the maximum depth of the Mingachevir reservoir decreased from formerly 83 m to 63 m according to Mammadov.[12]

Downstream of the Aras dam, a diversion dam was built which serves Mogan (Iran) and Mill (Azerbaijan) with irrigation and drinking water. Several more dams at the Aras are planned or under construction between Iran and Azerbaijan, among them the Khoda-Afarin dam and the

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[8] UNEP 2002, p. 63
[9] UNEP 2002, p. 65-66
[10] Ministry of Nature Protection of the Republic of Armenia 2010, p. XVI
[11] Mammadov, p. 8
[12] Mammadov, p. 8

Giz-Gale Si dam for hydropower and irrigation. Moreover, several dams are planned between Iran and Armenia.[13] As shown below, the bilateral utilization contributes to the urgent need of improving cooperation among the countries in the basin.

Agriculture

During the time of the Soviet Union, the South Caucasus was an important agricultural region, producing for the entire Union. As shown in table 3, agriculture is still the main employing sector in the countries, even though its contribution to the GDP ranges from only 6% in Azerbaijan to 19% in Armenia.

Today, irrigated agriculture makes up more than half of the total agriculture in all South Caucasus states, with 59% in Armenia, 69% in Azerbaijan and 75% in Georgia. Moreover, more than half of the total freshwater withdrawn is used for agricultural purposes, with a significant impact on the discharge of the Kura and Aras Rivers. In the absence of clear figures, it was estimated that water withdrawal for irrigated agriculture reduces the discharge of the Kura into the Caspian Sea by about 15-20%.[14]

	Armenia	***Azerbaijan***	***Georgia***
Contribution of agriculture to GDP	19%	6%	12%
Share of labor in agricultural sector	46%	38%	56%
Share of water used by agricultural sector	66%	68%	59%
Share of cultivated area equipped for irrigation (2007)	59%	69%	75%

Table 3: Relevance of agriculture in Armenia, Azerbaijan and Georgia; sources: Agricultural water use: CIA 2010; share of irrigation: FAO 2010b

After the collapse of the Soviet Union, the importance of agriculture decreased notably in Armenia and Georgia. In the latter country, the amount of water consumed by the sector in 2003 was one third of the amount in 1993 according to UNDP. In Armenia, the area of irrigated land decreased from 300,000 ha in 1989 to 135,000 ha in 2004. This is mainly caused by the deterioration of irrigation infrastructure. In Azerbaijan, the area of irrigated land increased slightly. However, water use decreased, mainly because water intensive crops were replaced by less water intensive ones.[15]

Biodiversity

Due to its geographical and climatic peculiarities, the river basin is characterized by an extraordinary diversity of natural ecosystems. These are threatened by direct human interferences, in particular changes in land use and resultant changes in land cover. Many natural ecosystems have been changed into arable lands, pastures and hay fields since the mid of the last century.[16] According to UNDP and GEF, forest and steppe areas have decreased considerably.[17] Commercial fishing was particularly harmful to aquatic species in the 1970s and 1980s.[18] In addition, biodiversity is threatened by climate change and

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[13] Faramarzi and Filipuzzi 2007, p. 8
[14] Imanov, p. 1
[15] UNDP 2007, p. 43
[16] UNEP 2002, p. 19
[17] UNDP and GEF 2006, p. 24
[18] UNEP 2002, p. 20

variability. Increased variations and long term changes in temperature and precipitation are a dangerous risk for flora and fauna with restricted areas of distribution.[19]

Vulnerability and Relevance of Climate Change

Little is known about the acceptable resource use limits in the basin.[20] In general, water resources are abundant in the South Caucasus but unequally distributed. Some areas which are exceptionally threatened by droughts and floods are particularly vulnerable.

In Armenia and Georgia, most of the water used for irrigation and industry is withdrawn from rivers, while the countries rely on groundwater for drinking purposes. Azerbaijan is particularly vulnerable, since the rivers provide about half of the country's drinking water and 60% of its irrigation water.[21] Moreover, Azerbaijan is the only South Caucasus state with a growing population which increases the pressure on water resources.[22] The fact that about three quarters of Azerbaijan's renewable water resources enter the country from its neighbors (table 4) underlines its dependence on upstream countries and the important transboundary dimensions, particularly from the Azerbaijani point of view become clear. In addition to this, Azerbaijan is threatened by the varying Caspian Sea level.

	Armenia	***Azerbaijan***	***Georgia***
Renewable water resources (km³)	7.77	34.68	63.33
External renewable water resources (km³)	0.91 (11.7%)	26.56 (76.6%)	5.2 (8.2%)
Total freshwater withdrawal (km³)	2.83	12.21	1.62
Water withdrawal per capita (2007, in m³)	920	1,415	372
Water balance (km³)	4.94	22.47	61.71

Table 4: Total Renewable Water Resources and Total Freshwater Withdrawal in Armenia, Azerbaijan and Georgia; source: FAO 2010b

Other factors affecting the river basin

Climate change is not the only threat to the Kura-Aras River Basin. Instead, the quality and quantity of water resources have been threatened by several other factors, increasing their vulnerability to climate change.

Water quality

The quality of the Kura and Aras rivers deteriorated significantly since the second half of the 20th century. However, there is little detailed information on the quality status due to the lack of a comprehensive monitoring system. Water quality degradation is one of the most important problems of the rivers. Pollution results from the following sources:[23]

- Untreated municipal wastewater leads to organic pollution
- Extensive use of pesticides and fertilizers in agriculture leads to high nutrient concentrations
- Industrial wastewater leads to chemical pollution

[19] UNEP 2002, p. 21, Department of Hydrometeorology 1999
[20] UNDP 2007, p. 44
[21] Campana and Vener, 2008
[22] UNDP 2007, p. 10
[23] Faramarzi and Filipuzzi 2003, p. 44

- Mining activities lead to heavy metal contamination

In the Kura basin, wastewater treatment facilities are, if existent, mostly not operational.[24] In the case that wastewater is treated, it usually only receives mechanical treatment. Biological and chemical treatment are not practiced in most cases.

Again, the pollution problem is an important factor for a possible conflict between upstream and downstream users. For instance, irrigation reservoirs downstream in Azerbaijan suffer from the discharge of untreated wastewater into the Kura River. Pollution from Mingechevir in central Azerbaijan and other upstream sections lead to a concentration of mineral oil and sulphates which is twice the sanitary norm according to USAID and Development Alternatives Inc. (DAI), measured downstream of the city of Mingechevir. The concentration of phenols and metals is respectively five and four times as high as the sanitary norm.[25]

Metallurgical and mining sites in Armenia and Turkey are of particular concern for the Aras River. Magnesium and heavy metals are discharged into the river, including copper, molybdenum and iron.[26] This adds to the high heavy metal content in the river caused by the natural occurrence of chromium, copper and nickel.[27] Again according to USAID and DAI, the concentration of metals at the confluence of Aras and Kura exceeds permissible levels by up to nine times. The concentration of phenols is six times higher. Mineral oil and sulphates are two and three times higher, respectively.[28]

A 2003 study on water quality in the basin concludes that a large share of the pollution results from former Soviet times. This includes a massive use of pesticides, chemical fertilizers and defoliants which were used in Azerbaijan's agriculture and the use of polluting chemical production plants in Armenia.[29] In addition, the economic collapse of the South Caucasus states after gaining independence led to deteriorating infrastructure including treatment facilities.[30] In the case that climate change leads to less water quantity, this might have negative impacts on water quality as well, since less water has less capacity to dilute pollutants.

Water quantity

The flow level of both rivers is highly variable throughout the year. According to a 2005 study by UNDP and the Swedish development agency SIDA, a large share of water is abstracted from the rivers by human activities. The document suggests that this reduces the discharge of the Kura and Aras by 40% and 27%, respectively, at the confluence of the two rivers. These activities include direct abstraction, the construction of artificial reservoirs leading to increased evaporation and urbanization leading to increased water demand.[31] Deforestation

[24] UNDP 2007, p. 55

[25] Since it was not possible to access the cited document, it is not clear which sanitary norm is meant here. UNDP 2007, p. 48, citing USAID and DAI 2004

[26] Farmarazi and Filipuzzi 2007, p. 9

[27] UNDP 2007, p. 48-49

[28] UNDP 2007, p. 49

[29] Farmarazi and Filipuzzi 2007, p. 9

[30] Ewing 2003, 23, 44

[31] UNDP and SIDA 2005, quoted in UNDP 2007, p. 35

might also contribute, since natural soil fauna has a function of retaining and regulating the subsurface flow, while cleared land has less water holding capacity. [32]

Anthropogenic interventions in the natural flow of the rivers have also led to an increased risk of flooding, in particular in downstream countries. This includes changes in land cover and the degradation of natural floodplains. In addition, flood protection infrastructure deteriorated throughout the basin. The danger of flooding has been lowered through reservoirs, dikes and walls but at the same time, channelization and straightening of river courses have increased the risk. In the case of floods, poor information and communication concerning meteorological occurrences contribute to an insufficient preparation in downstream countries.[33]

Water Demand

As shown above, agriculture is the major water user in the South Caucasus, even though its contribution to the national GDPs is below one fifth in all countries. It was estimated that about 40 to 60% of the water which is intended to be used for agricultural purposes is lost in the distribution systems. Most irrigation canals are open and unlined with high filtration rates.[34] Domestic water supply is characterized by similar losses. About 20 to 40% of the water is lost in the distribution networks. However, thorough investigations were only done in Armenia. Although hydropower is a non consumptive water user, it stores a large amount which cannot be used for a certain time. Armenia, Georgia and Iran are planning to construct new hydropower stations and reservoirs.[35]

It is unclear how water demand will develop in the future. Industrial water withdrawal has decreased after 1990. However, an economic upturn and the need to improve life quality are likely to turn this trend, in particular if it is connected to an expansion of irrigated lands. However, it is not clear whether the importance of agriculture will increase or decrease in the coming decades, nor whether water will be used in a more efficient way.[36] A similar uncertainty concerns the future development of industrial water demand, which decreased significantly after the collapse of the Soviet Union and increased slightly after the production was partly resumed.[37] The future amount of water used for all purposes will also largely depend on interventions such as water pricing, metering, rehabilitation of infrastructure and water saving technologies.

According to UNDP, domestic water demand is likely to increase in the future due to improving living standards. However, investments in water supply infrastructure and improved operation and maintenance would reduce water losses.[38] In addition, the population will most likely decrease in Armenia and Georgia, but increase in Azerbaijan.[39]

[32] UNDP 2007, p. 43-44
[33] UNDP 2007, p. 72
[34] UNDP 2007, p. 42
[35] UNDP 2007, p. 45-46
[36] UNDP 2007, p. 45
[37] UNDP 2007, p. 45
[38] UNDP 2007, p. 44
[39] CIA 2010, UNDP 2007, p. 45

Historical trends

Water quality and quantity data were recorded by the Soviet Union until 1989. Afterwards, most of the monitoring was stopped due to political and/or economic pressure in the South Caucasus states. In addition, the quality of existing data was described as doubtful.[40]

National data obviously do exist but are not easy to access. In Georgia for instance, meteorological observations started in 1844 and hydrological observations started in 1905. In the 1980s, the country was equipped with numerous standard and specialized observation stations. Since the early 1990s however, the number of stations decreased essentially.[41] This is confirmed by the fact that the countries rely on historical data from the period 1961-1990 in their national reports (see below).

According to a UNDP report, the hydro-meteorological services of South Caucasus Republics reported an increase in the frequency of hydro-meteorological occurrences, such as floods, mudflows and snow slides during the last decades. However, the report does not contain any statistical data which would confirm this development.[42] Similarly, Armenia's Ministry of Nature Protection reports in its Second National Communication to the UNFCCC, that the "intensity and frequency of hazardous hydro-meteorological phenomena has increased" significantly in the period 1985-2005.[43]

According to the WWF, climate is already changing in the South Caucasus. Evidence includes increasing temperatures, shrinking glaciers, a rising sea level, reduced snowfall and a snowline which is moving upwards.[44]

Temperature

According to UNDP and GEF, on the major part of the river basin the temperature increased by 0.3 to 0.6°C during the 20th century. The warming was highest in Borjomi Gorge, Lower Kartli, Greater Caucasus, the Kura-Aras Lowland and Nakhichevan (the latter three regions are located in Azerbaijan) with 1 to 1.3°C. In Javakheti, Inner Kartli and Northeast Iran, temperatures decreased.[45]

Similarly, the WWF reports that temperatures increased by 0.5 to 0.6°C in Azerbaijan since the 1880s. In Georgia the mean annual temperature increased in the east and decreased in the west, including the Greater Caucasus.[46] According to Armenia's Second National Communication, the mean annual temperature in the country increased by 0.85°C from 1935 to 2007, with accelerated changes since the 1990s. The increase mainly refers to summer months with the hottest summer since 1929 in 2006.[47]

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[40] Ewing 2003, p. 28-29
[41] Ministry of Environment Protection and Natural Resources of Georgia 2009, p. 202
[42] UNDP and GEF 2006, p. 16
[43] Ministry of Nature Protection of the Republic of Armenia 2010, p. 48
[44] Sylvén et al. 2008, p. 11
[45] UNDP and GEF 2006, p. 10-11
[46] Sylvén et al. 2008, p. 11
[47] Ministry of Nature Protection of the Republic of Armenia 2010, p. 48-49

Precipitation
Precipitation decreased in most areas in the basin. The average trend is 2-12 mm in ten years. The most significant decrease was noted in west Azerbaijan. Almost no changes took place in the Smaller Caucasus and Nakhichevan. UNDP and GEF point to a possible correlation between warming and decrease in precipitation.

According to WWF, the reduction in precipitation was highest in Armenia and insignificant in Azerbaijan. In Georgia and Armenia, rainfall records vary considerably among location.[48] In the latter country, annual precipitation decreased by 6% from 1935 to 2007 at the national average. Northeastern areas and the Ararat Valley became more arid, while southern and northwestern areas and the Lake Sevan basin have experienced a significant increase in precipitation.[49]

Discharge
River flow in the South Caucasus is characterized by very high annual and seasonal variations. In Armenia, the ratio for maximum to minimum river flow reaches up to 10:1.[50] The changes in the discharge of the rivers in the basin are heterogeneous. The long term discharge is decreasing in some rivers and increasing in others. Given the available data, a link between melting glaciers and increasing river discharge is likely. The main rivers and tributaries which are not fed by glaciers have a linear or decreasing water level. In that case, it is almost impossible to directly correlate the reductions to climate change, since direct anthropogenic water withdrawal is very intensive.[51] Moreover, a high annual variation is a common feature of the rivers and tributaries. The graphs below only show the annual average discharge and thus conceal climate variability occurrences like droughts and floods.

Aras River
From 1946 to 1996, the annual discharge at Saatly (Azerbaijan) decreased from more than 250 m³/sec to slightly more than 50 m³/sec (figure 3).

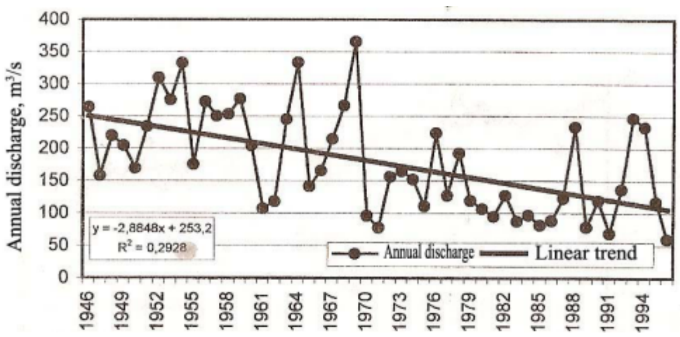

Figure 3. Annual flow changes of the Aras River at Saatly; source: UNDP and GEF 2006, p. 20

The tributaries of the Aras show positive and negative trends. The flow of the Vokhchi tributary in Armenia increased (figure 4) while a negative trend was observed at three other Armenian tributaries, namely the Vorotan, Azat and Sevjur. This could result from the fact that the Vokhchi is fed by glaciers whose ice is rapidly melting caused by an increasing

48 Sylvén et al. 2008, p. 11
49 Ministry of Nature Protection of the Republic of Armenia 2010, p. 48
50 Ministry of Nature Protection of the Republic of Armenia 2010, p. 54
51 UNPP 2008

temperature. On the contrary, the watersheds of the Azat and the Sevjur do not contain any glaciers.[52]

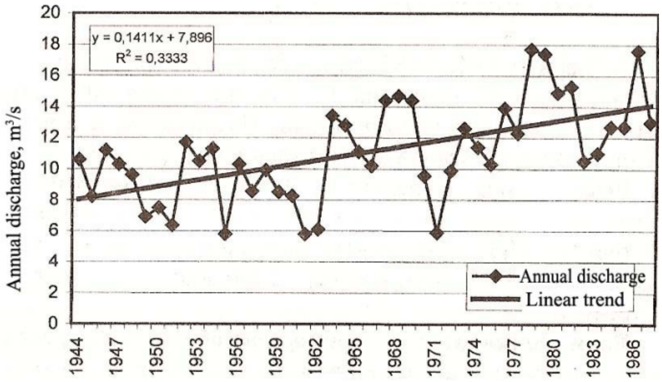

Figure 4. Annual flow changes of the Vokhchi River in Kafan; source: UNDP and GEF 2006, p. 20

Kura River

The discharge of the Kura River in the last decades was largely variable. In Tbilisi for instance, the long term trend was uniform from 1930 to 1995, even though the changes between years were partly significant (figure 5).

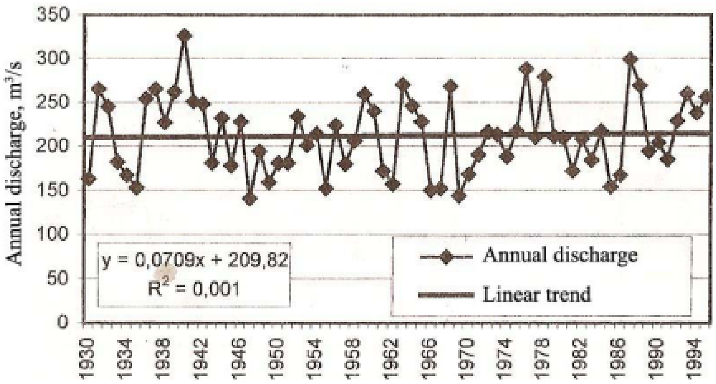

Figure 5. Annual flow changes of the Kura River in Tbilisi; source: UNDP and GEF 2006, p. 17

The development of the level of the tributary Aragvi which is fed by glaciers is positive (figure 6). Downstream in Azerbaijan a clear negative trend is visible. In Mingechevir where a huge reservoir is located, the flow decreased almost by half (figure 7). According to UNDP, the river flow at Mingechevir decreases by 2 km³ each year.[53] Further downstream in Salyan which is located close to the delta at the Caspian Sea, the flow decreased from about 550 m³/sec in 1938 to less than 400 m³/sec in 1998.[54]

[52] UNDP and GEF 2006, p. 19
[53] UNDP 2008
[54] UNDP and GEF 2006, p. 17-18

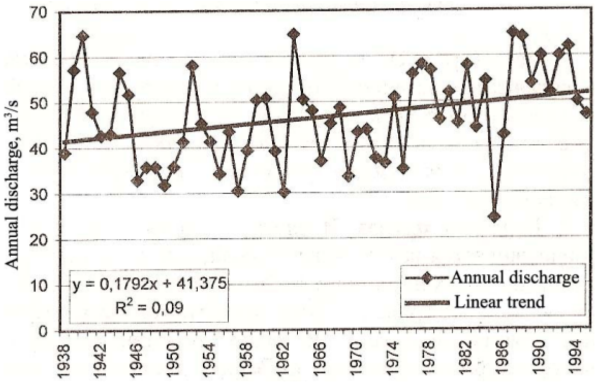

Figure 6. Annual flow changes of the Aragvi River in Zhinvali; source: UNDP and GEF 2006, p. 19

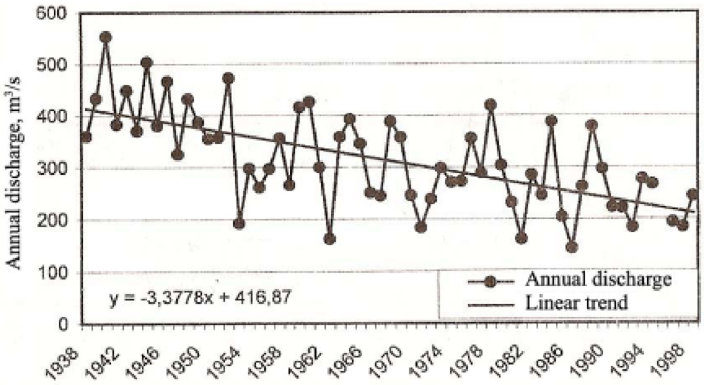

Figure 7. Annual flow changes of the Kura River in Mingechevir; source: UNDP and GEF 2006, p. 18

The tributaries of the Kura River which flow into the Mingechevir reservoir show unequal trends. The rivers Great Liakhvi and Aragvi show a positive trend while the trend is stable for the Algety River and negative for the Ktsia-Khrami, Agstev and Iori rivers. Again, this might be connected to an intense melting of glaciers concerning the former two rivers and decreasing precipitations and increasing evaporation.[55]

In general, increasing levels are obviously connected to increasing ice melting of glaciers which is a direct effect of higher temperatures. A reduction in discharge is partly caused by higher evaporation, again caused by increased temperatures. However, UNDP and GEF suggest that the construction of infrastructure like reservoirs and irrigation canals plays a bigger role.[56]

Variability

Monthly discharge figures are available for the period 1930-1984 at the meteorological station at Surra, which is located 140 km from the outlet of the Kura in Azerbaijan. Figure 8 compares the hydrographs for the wettest and the driest year recorded and an average of all years recorded. It shows that the difference is based on the flood season, while the base flow is relatively equal, once again proving the occurrence of floodings.

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[55] UNDP and GEF 2006, p. 18
[56] UNDP and GEF 2006, p. 23

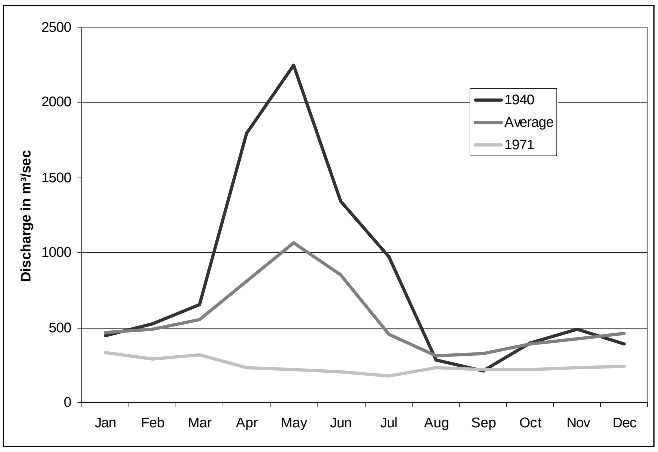

Figure 8. Yearly hydrographs at Surra, Azerbaijan (1930-1984); source: Center for Sustainability and the Global Environment 2010

Frequent floods happen in the river basin, caused by the melting of ice and snow, rainfall and geographic features such as changes in land cover. They take place mainly between April and October and are not a new phenomenon. Records show that floods at the Aras happened each 10 to 17 years in the second half of the 19th century.[57]

Sea Level

Moreover, the Caspian Sea level has varied considerably during the 20th century. In the 1930s, the level dropped by 2 meters mostly within a period of five years,[58] followed by an additional decrease by about 1 meter until the 1970s. From 1978 to 1995 however, the level increased by about 2.5 meters (figure 9). The rising sea level led to the inundation of 485 km²[59] and saltwater intrusion in coastal groundwater aquifers.[60] According to an article in the journal Climate Dynamics, these shifts are caused by shifting "regional climate variability modes such as the North Atlantic Oscillation (NAO) and the El Niño Southern Oscillation (ENSO)".[61]

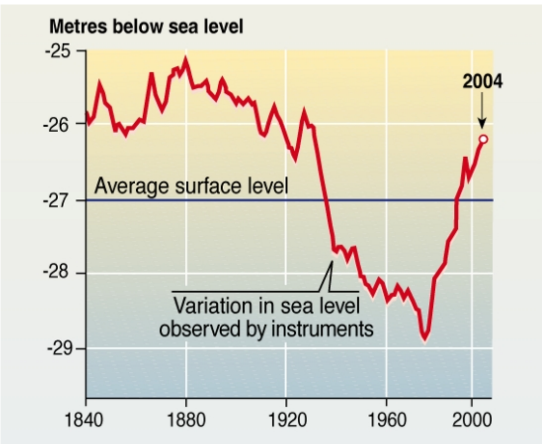

Figure 9. Changes of the Caspian Sea Level (1840-2004); source: UNEP and GRID-Arendal 2007

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[57] Mammadov, p. 4
[58] Elguindi and Giorgi 2007, p. 365
[59] Sylvén et al. 2008, p. 13
[60] ADB 2008, p. 3-16
[61] Elguindi and Giorgi 2007, p. 365

Future projections

Validity and consent of projections

Recent developments compromise the reliability of climate change projections,[62] clearly emphasizing the strong need to evaluate the validity of future climate change projections.

One way to do this is to check how many of the projections show similar developments. In order to assess the credibility of climate change projections in the Kura-Aras River Basin, seven spots in that area have been examined using the World Bank Climate Change Knowledge Portal, which compares the projections of 20 General Circulation Models (GCMs) used by the IPCC, based on the moderate A1B scenario.[63] They show the projected average situation in the period from 2030 to 2049 and compare it to the recorded data of the period from 1980 to 1999. The tool shows how many of these models agree on the direction of the prediction (for instance: more precipitation or less precipitation).

Figure 10. Locations used with the Climate Change Data Portal; map based on OpenStreetMap (http://www.openstreetmap.org/) contributors, CC-BY-SA (http://creativecommons.org/licenses/by-sa/2.0/)

The analysis was done using the locations of Salyan, close to the mouth of the Kura in Azerbaijan, Mingechevir (Azerbaijan), Tbilisi (Georgia), Nakhichevan (Azerbaijan), Yerevan (Armenia), Maku (Iran) and Kars (Turkey). All locations are shown in a map in figure 10. The highest uncertainty exists concerning mean annual precipitation. In Mingechevir, 12 out of 20 GCMs project decreasing rainfall for the period from 2030 to 2049. The share of models projecting a negative trend increases to 13 in Salyan, 15 in Nakhichevan, 16 in Tbilisi and Kars, and 18 in Yerevan and Maku. Concerning precipitation intensity and consecutive dry days, the models agree more. A positive trend concerning both criteria is projected by 6 or 7

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[62] The Guardian 2010

[63] As a basis for projections, the IPCC uses about 40 Scenarios with different presumptions about the future development of the worldwide human society, concerning the degree of population growth, economic and social development, technological changes, use of resources, globalization and ecologic orientation. The scenarios are categorized into four groups, namely A1, A2, B1 and B2. A1 is further divided according to the kind of resources used (A1T: non fossile; A1B: balanced; A1FI: fossile intensive). The A1B scenario which is used by the Climate Change Data Portal assumes a trong population growth where the world population reaches a peak in the middle of the 21st century and declines afterwards, a quick adoption of new, efficient technologies and rapid economic growth. In addition, the scenario assumes increasing globalization and approximation of per capita income. A1B assumes a balanced usage of fossil and non-fossil energy sources. For more information on IPCC scenarios, please refer to IPCC 2000

out of 8 models in all locations except for Salyan, where all 8 models agree on increasing precipitation intensity. Concerning runoff, the uncertainty display does not seem to work.[64] Furthermore, all models agree concerning temperature, predicting an increase.[65]

	Mean annual precipitation	*Precipitation Intensity*	*Consecutive dry days*
Salyan (Azerbaijan)	(13/20)	(8/8)	(6/8)
Mingechevir (Azerbaijan)	(12/20)	(6/8)	(7/8)
Tbilisi (Georgia)	(16/20)	(7/8)	(6/8)
Nakhichevani (Azerbaijan)	(15/20)	(7/8)	(6/8)
Yerevan (Armenia)	(18/20)	(7/8)	(7/8)
Maku (Iran)	(18/20)	(7/8)	(7/8)
Kars (Turkey)	(16/20)	(7/8)	(7/8)

Table 6. Uncertainty of future climate change, expressed in number of IPCC models projecting the same (positive or negative) change; source: World Bank 2010

Possible future development

Keeping in mind the uncertainties of climate projections, the following is projected by the aforementioned tool for the period 2030-2049 compared to 1980-1999:

- The **mean annual temperature** will increase by 2°C in all selected locations except for Mingechevir, where the increase is 1°C.
- **Precipitation** is projected to decrease by 5% in Tbilisi, Nakhichevan and Kars and by 8% in Yerevan and Maku. In Mingechevir and Salyan, it is not clear if precipitation will increase or decrease.
- Daily **precipitation intensity** is projected to increase by 4% in all locations except for Salyan and Nakhichevan, where the increase is 5%.
- **Consecutive dry days** are projected to increase by 2 days in Mingechevir, 3 days in Nakhichevan and Maku, 4 days in Salyan and Tbilisi and 5 days in Yerevan and Kars

A table containing all results is shown in annex 2, while the aggregated data are shown in table 7.

	Mean annual precipitation	*Precipitation Intensity*	*Consecutive dry days*
Salyan (Azerbaijan)	**?**	**+**	**+**
Mingechevir (Azerbaijan)	**?**	**+**	**+**
Tbilisi (Georgia)	**-**	**+**	**+**
Nakhichevani (Azerbaijan)	**-**	**+**	**+**
Yerevan (Armenia)	**-**	**+**	**+**
Maku (Iran)	**-**	**+**	**+**
Kars (Turkey)	**-**	**+**	**+**

Table 7. Aggregated trend of future climate change; source: World Bank 2010

[64] Personal Communication 2010
[65] World Bank 2010

Sea level

Concerning the Caspian Sea level, Elguindi and Giorgi simulated future climate conditions for the period 2071-2100 over the whole Caspian Sea Basin compared to 1961-1990, using a GCM and a Regional Climate Model (RCM) and assuming the A2 scenario. They find that precipitation will increase in the cold season while temperature and evaporation will also rise. The losses through evaporation are expected to be higher than the gains through increased precipitation in cold seasons, so that the sea level will fall by 3 to 4.5 meters by 2100 according to the projection. The authors emphasize that this tendency may not be representative for the 21st century and point to the large multi-decadal variability in the precipitation regime in the region and its impacts on the sea level.[66]

National projections

The countries did their own projections on climate change in their respective national communications to the UNFCCC.

Armenia: The Ministry of Nature Protection of Armenia recently published its second communication. Seven GCMs and the A2 (high emission growth) and B2 (low to moderate emission growth) scenarios were used. According to the projection, the trend of increasing temperatures in summer months will continue with an average increase by 4.8 to 5.7°C by 2100. In the south of Armenia, the temperature increase will be moderate. Moreover, all models project a decreasing annual mean precipitation by 8 to 27% by 2100 with the most intense reduction during summer months. In west Armenia (lowlands and Ararat valley), precipitation is however expected to decrease. The communication contains an estimate of uncertainty based on an empirical statistical assessment of the period up to 2006. It says that the uncertainty is at about 15-20% concerning temperature and 50% concerning precipitation.[67]

Concerning river discharge, the document projects a decreasing flow in most rivers and a modest increase in a few, assuming the A2 scenario with high emission and temperature increase. The Aras River is not part of the projection. Increasing river discharge is only expected in the Vorotan and Voghji Rivers, two left tributaries of the Araks, due to increasing precipitation. In total, the projection forecasts a river flow reduction by 6.7% by 2030, 14.5% by 2070 and almost one quarter (24.4%) by 2100 compared to the average 1961-1990.[68]

Azerbaijan: In its first national communication (2000), Azerbaijan used data from 16 meteorological stations for the period 1961-1990 as a baseline scenario for five GCMs, assuming a doubling of CO_2 concentrations. The models project an increase in temperature by 4.1-5.8°C by 2100. However, Azerbaijani specialists project an increase of only 2°C, taking into account "the regional peculiarities of real climatic parameters change and global background." The communication indicates the role of sulfate aerosols, with a mitigation effect on greenhouse gases.[69] Concerning precipitation, two models project an increase and two a reduction with the fifth model projecting insignificant changes. However, they largely agree that precipitation will increase in winter and decrease in summer.[70] The communication

[66] Elguindi and Giorgi 2007
[67] Ministry of Nature Protection of the Republic of Armenia 2010, p. 48-53
[68] Ministry of Nature Protection of the Republic of Armenia 2010, p. 55
[69] Republic of Azerbaijan, p. 67
[70] Republic of Azerbaijan, p. 64-68

projects a reduction of river discharge by 15-20% by 2100, given a temperature increase of 2-4.5 °C. In addition, the Caspian Sea level might rise by 1.2 to 1.5 meters by 2020-2040 according to the communication, inundating 130-160 km².[71] The inconsistent projections and the uncertainty mentioned by Elguindi and Giordi[72] underline that for the time being there is no certainty about the future development of the Caspian Sea level.

Georgia: In its second communication (2009), Georgia compared 17 GCMs with a database for the baseline period from 1961-1990, assuming the A2 scenario. Georgia projects an increase in temperature by 3-5°C and a decrease in precipitation by 9-13% by the year 2100 compared to the average values of the period 1961-1990. These trends are more intense during the summer concerning both precipitation and temperature. [73]

Impacts of climate change and variability

The WWF projects severe impacts from global warming in the South Caucasus. An increasing temperature will lead to reduced water availability and more droughts. Glaciers will continue melting "possibly to an extent where hardly any glaciers will be left at the end of the 21st century."[74] This is particularly crucial since ice from glaciers is an important regulator of the water flow of the main rivers and their tributaries. It is important to note that due to the importance of glaciers in the hydrological regime of the river basin, an increasing temperature is extremely relevant for the region.

Before the glacier ice disappears, the rapid melting will provide abundant water including floods and causing erosion. The floods will further increase through the projected increase in precipitation intensity. Once the ice has melted, the rivers will increasingly depend on precipitation. The discharge will presumably increase in rainy seasons, since precipitation will not be stored in glaciers and snow, and decline in dry seasons. Those major floods which are caused by intense melting[75] will stop to happen once the glaciers disappeared.

Increasing temperatures contribute to increased water evapotranspiration which suggests decreasing water availability. However, the hydrological cycle is much more complex. Besides this, it is also important to note that increasing temperatures increase water demand.[76]

Although no detailed studies on water quality in the region are available, reduced flow generally has less capacity to dilute pollutants, which contributes to water quality degradation.[77] Irrigation might be affected by water shortages, leading to less productive agriculture. The same applies to water supply and sanitation, where less water can lead to severe public health problems. The reduced availability of water also reduces the capacity of hydropower in the basin.[78]

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[71] Republic of Azerbaijan, p. 13
[72] Elguindi and Giorgi 2007, p. 376
[73] Ministry of Environment Protection and Natural Resources of Georgia 2009, p. 98-101
[74] Sylvén et al. 2008, p. 17
[75] UNEP 2002, p. 63
[76] UNDP 2008
[77] UNDP 2007, p. 38
[78] UNDP 2007, p. 35

A reduction in runoff would probably lead to a decrease in reservoir water. Together with rising temperatures, it would also lead to increased drought and desertification.[79] In the case that the sea level continues to rise, coastal areas in Azerbaijan will suffer from inundations and saltwater intrusion in groundwater.[80]

[79] UNEP 2002, p. 66
[80] ADB 2008, p. 3-16

Part two: Institutions, strategies and activities

Political background

The current political situation with several ethnic, religious and cultural conflicts is a crucial obstacle to improved transboundary river basin management. These started soon after the political responsibilities were transferred from the Union of Soviet Socialist Republics (USSR) to the newly established states in 1991.[81]

Figure 11. Political map of the South Caucasus, including conflict regions; source: derived from Wikimedia Commons 2008

The South Caucasus is home to more than 50 ethnic groups. Major ongoing conflicts include the following:

- *the Nagorno-Karabakh conflict*: Nagorno-Karabakh is a region in southwest Azerbaijan with mainly Armenian population. The area is controlled by the Armenian military and also known as the Nagorno-Karabakh Republic which declared its independence from Azerbaijan in 1991.[82] A cease-fire was signed in 1994 and has held until today.[83] The relations between Azerbaijan and Armenia suffer significantly from this conflict.

- *the South Ossetia conflict*: South Ossetia is located in the north of Georgia. Just like Abkhazia (which is not located in the river basin), it considers itself an autonomous republic. However, it has only been recognized by Russia and Nicaragua. Military clashes between Russia and Georgia in 2008 showed that the conflict can escalate quickly.[84]

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[81] Vener 2006, p. 2
[82] BBC 2009
[83] Vener 2006, p. 10
[84] Wittich and Maas 2009, p. 8

Moreover, the region is of high geo-strategic importance for Russia, Iran, Europe and the United States, not at least due to the presence of Caspian oil and gas resources and pipelines.[85]

The regional conflicts can be regarded as an important obstacle to increased cooperation on water resources. For instance, a contract between Armenia and Azerbaijan concerning transboundary water resources management is unlikely before the Nagorno-Karabakh conflict is solved.[86] These conflicts have been tackled by several transboundary projects with donor support, including UNDP, USAID, European Union, NATO and OSCE.[87] Experience shows that cooperation is difficult but possible.

Germany is active in the issue through the Caucasus Initiative by the Federal Ministry for Economic Cooperation and Development. It was launched in 2001 and aims at increasing cooperation among the South Caucasus states of Armenia, Azerbaijan and Georgia in the sectors of sustainable economic development, energy, environment and democracy, communal development and the rule of law.[88] For instance, a Transboundary Joint Secretariat was established in 2007 with the three countries participating in joint nature conservation, showing that cooperation is possible.[89] Moreover, the national Ministries of Environment work together in the Regional Environmental Center for the Caucasus, founded in 1999. The center assists the Caucasus states in solving environmental problems and supports civil society participation, free exchange of information and cooperation at all levels.[90] It is important to keep in mind that in the context of IWRM, many measures at the local level have an impact on the whole transboundary watershed.

Transboundary agreements

Several bilateral agreements on joint water resources management exist. Some of them were made during the time of the Soviet Union. According to UNDP, Armenia and Azerbaijan consider themselves bound to these treaties.[91] Moreover, Georgia has made bilateral agreements with Armenia and Azerbaijan in 1997.[92]

USSR and Turkey

- 1927: A convention was agreed according to which water of the boundary rivers is shared equally between Turkey and the USSR. The convention provides for a joint monitoring commission, measuring the discharge at several observation stations twice per year.

- 1927: Another convention was signed in the same year concerning the protection of water quality.

[85] Vener 2006, p. 13-14
[86] Vener 2008, p. 7
[87] UNDP 2007, p. 95
[88] BMZ 2010
[89] Transboundary Joint Secretariat for the Southern Caucasus 2010
[90] Regional Environmental Centre for the Caucasus 2006
[91] UNDP 2007, p. 10
[92] UNDP 2007, pp. 10-11

USSR and Iran

- 1957: An agreement between the Shakhinshakh Government of Iran and the USSR assigns both parties to ensure preservation of the boundary waters and to protect them against pollution. Information on the quantity of water and possible emergencies (like floods) was agreed to be exchanged.
- 1957: Another agreement was signed in the same year concerning the joint utilization of transboundary waters. It assigns the 50/50 sharing of water and energy resources to both parties.

Armenia and Azerbaijan

- 1974: The Soviet Socialist Republics of Armenia and Azerbaijan agreed on the equal joint utilization of the water of the Vorotan River, a tributary to the Aras.

Georgia and Azerbaijan:

- 1997: The Ministry of Environment in Georgia and the State Committee of Ecology and Nature Management of the Republic of Azerbaijan (which is now the Ministry of Ecology) agreed on a Memorandum of Understanding on cooperation in developing and implementing pilot projects for monitoring and assessing the status of the Kura River Basin.
- 1997: The Governments of Georgia and Azerbaijan agreed on cooperation in Environmental Protection.

Georgia and Armenia:

- 1997: The Governments of Georgia and Armenia agreed on cooperation in Environmental Protection.

For most of these agreements, it is not clear how relevant they are in practice. However, the Aras dam which was completed in 1971 was built on the 1957 agreement between Iran and USSR on transboundary water management. In addition, more bilateral irrigation and power generation facilities have been constructed at the Aras River. [93]

Azerbaijan signed the UN Convention on the Protection and Use of Transboundary Water Courses and International Lakes in 1992 and ratified it in 2000. However, Georgia and Armenia did not sign the convention.[94] Once again, the weak position of the vulnerable downstream country becomes visible.

Responsible institutions

Responsibilities on river management remain at the national level in all basin countries. According to UNDP, some of them have reformed their institutional and legal framework during the last years.[95] The national communications to the UNFCCC were written by

[93] Faramarzi and Filipuzzi 2007, p. 8
[94] United Nations Treaty Collection 2010; Mammadov, p. 11
[95] UNDP 2007, p. 24

national ministries in all three South Caucasus countries. In the following, the main responsible institutions at the national levels are briefly described.

Armenia: Structural reforms in the water sector started in 1999 with an Integrated Water Resources Management Project.[96] A national water code was adopted in 1992 and revised in 2002 concerning the compatibility with the European Water Framework Directive.[97] The new code includes the concept of integrated basin management and economic aspects like cost recovery. Since 2002, responsibilities are allocated as follows: At the national level, water systems are managed by the State Water Systems Committee of the Ministry of Territorial Administration. The Water Resources Management Agency under the Ministry of Nature Protection is responsible for water resources protection and management,[98] including water availability, use efficiency and protection of environmental needs.

Moreover, five primary Basin Management Organizations are involved in preparing water management and allocation plans at the river basin level. They control the protection of water resources. According to UNDP, the State Hydrometeorological and Monitoring Service monitors river flows and the water levels of reservoirs and lakes through 92 observation points. Water quality is monitored by the Environmental Impact Monitoring Center, using 131 observation points.[99] Tariffs are expected to be set by the Public Services Regulatory Commission. Armenia adopted a National Water Program in 2006 focusing on environmental sustainability and meeting domestic and industrial water needs with short-, mid and long-term programs till 2021. A State Water Cadastrate (SWC) was developed, registering quantitative and qualitative water indicators.[100]

Armenia ratified the UNFCCC in 1993 and the Kyoto Protocol in 2002. The first and the second national communication to the UNFCCC have been published in 1998 and 2010 by the Ministry of Nature Protection, indicating that it acts as main institution for climate change. The same ministry acts as Designated National Authority for the Clean Development Mechanism of the Kyoto Protocol.[101]

Azerbaijan adopted its water code in 1997.[102] The Ministry of Ecology and Natural Resources is responsible for the conservation and protection of water resources. It is assigned to set and control standards of minimal allowed discharges and to evaluate the status of ground and surface water. The Department of Environmental Protection under the Division of Ecology and Environmental Policy monitors and implements environmental acts. Concerning water for irrigation, the Joint Stock company for Amelioration and Water Economy under the Ministry of Agriculture controls water resources and their use.[103] The national communication was published in 2000 by the Ministry of Nature Protection.

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[96] Ministry of Nature Protection of the Republic of Armenia 2010, p. 54
[97] Vener 2006, p. 29
[98] Ministry of Nature Protection of the Republic of Armenia 2010, p. 54
[99] UNDP 2007, p. 25, 27
[100] Ministry of Nature Protection of the Republic of Armenia 2010, p. 54
[101] Ministry of Nature Protection of the Republic of Armenia 2010, p. 10, 33
[102] Vener 2006, p. 29
[103] UNDP 2007, p. 27-28

Armenia's Adaptation Needs In its Second National Communication (2010), Armenia proposes a wide range of adaptation measures related to water resources, categorized in (i) accurate assessment of water reserves (ii) institutional and (iii) technical measures for efficient use of water resources (iv) extensive storage of water resources and (v) water loss reduction. A detailed list is shown in annex 3.

Georgia: Under the 1997 water code,[104] surface and groundwater are controlled by the Ministry of Environment Protection and Natural Resources, including the monitoring of water quantity and quality and pollution control. The same ministry published the second national communication in 2009. Water use for irrigation purposes and drinking water quality are supervised by the Ministry of Agriculture and Food.[105]

Local strategies

Some climate change strategies have been incorporated into national policies. For instance, Armenia has adopted a National Action Plan to Combat Desertification in 2002. The Strategy on National Security (2007) provides for the integration of Armenia into organizations which are involved in monitoring and prevention of natural and technological disasters. National poverty reduction documents do exist in the countries, but according to the WWF they do not include any aspects concerning climate change and adaptation.[106]

All countries which signed the United Nations Framework Convention on Climate Change (UNFCCC) are required to submit national communications on the implementation of the convention, including the South Caucasus states.[107] In the case of Azerbaijan, concrete priority adaptation measures are identified in its first communication report of the year 2000. These include the reconstruction of main channels and irrigation systems, the construction of new reservoirs and the identification of regions which are most vulnerable to climate change. Azerbaijan estimates the total cost for adaptation measures to more than USD 3.2 billion or 3.7% of the national GDP[108], which is exceptionally high compared to estimates by other countries. Out of this, the cost for water resources related projects is about USD 750 million.[109] The latest communications of Armenia (2010) and Georgia (2009) contain similar lists of possible adaptation measures without cost estimates.[110] A list of all proposed adaptation measures concerning water resources is shown in annex 3.

Possible adaptation measures

Adaptation to the impacts of climate change can be done in several ways. Most of the following measures recommended for adaptation directly target flooding in rivers, which is expected to increase in the future. Floods already occurred in the 19th century and are not a new phenomenon. However, the rising temperature plus increasing rainfall intensity significantly increase the risk of floods in rivers. Since floods are likely to happen with and

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[104] Vener 2006, p. 29
[105] UNDP 2006, p. 29
[106] Sylvén et al. 2008, p. 22
[107] UNFCCC 2010b
[108] CIA 2010
[109] Republic of Azerbaijan 2000, p. 81-82
[110] UNFCCC 2010

without climate change, but their size is likely to increase due to climate change, measures targeting increased flood risks in the river system can be classified as low regret measures. It should be noted that the glaciers might disappear entirely by the end of the century which would again decrease the risk of flooding.[111]

A second category is adaptation to drought and water quality issues, in particular in Armenia and Azerbaijan. Since these developments are likely even in the complete absence of climate change, measures in that category are no regret measures.

In the coastal areas of Azerbaijan, things are different. The Caspian Sea level decreased during a long time in the last century, but increased rapidly since the 1970s. As shown above, the future sea level development is not clear. Measures targeting the risk of flooding at the coast of Azerbaijan or a decreasing sea level can thus not be recommended. In the following, several suitable adaptation measures are suggested.

Research

A 2009 document published by UNDP and the Stockholm Environment Institute (SEI) suggests several adaptation measures for Armenia. One of them concerns the urgent need for more research about climate change impacts and suited adaptation measures.[112] Given the lack of hydrologic information in the Kura-Aras River Basin, this recommendation can be transferred to Azerbaijan and Georgia. This includes the establishment and operation of a transboundary monitoring system on discharge, precipitation, runoff and water quality. Based on such a monitoring system, an early warning system might be established, informing downstream users of hazards and avoiding damage.[113] In addition, a good monitoring system provides the basis for a sustainable flood control and risk management strategy.[114] As shown below, many donors are already active in improving transboundary research.

Spatial planning

In areas which are threatened by flooding, damage could be avoided by an adequate land use policy. Besides the restriction of land use and settlements in flood risk zones, this includes a strategic vegetation management, for instance through reforestation.[115] Improved spatial planning could also have a positive impact on water quality.

Infrastructure

Another recommended adaptation approach is the improvement of existing water infrastructure.[116] Future developments might bring stronger floods and storms which could have disastrous impacts. The construction and/or rehabilitation of adequate infrastructure would reduce the risk of such effects.

Decreasing water availability might be targeted through water loss reduction measures. Moreover, water storage facilities would help to regulate the flow and reduce the negative

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[111] Sylvén et al. 2008, p. 17
[112] UNDP and SEI 2009 , p. 90-91
[113] UNDP 2007, p. 80
[114] UNDP 2007, p. 80
[115] UNDP 2007, p. 80
[116] UNDP and SEI 2009 , p. 91

impacts caused by droughts. Concerning water quality, treatment facilities might be constructed and rehabilitated. Decentralized stormwater practices could contribute at the local level.

Water Demand Management

Water resources are under pressure in particular in Armenia and Azerbaijan. Consequently, Azerbaijan's national communication suggests several adaptation measures with the objective to reduce water demand, all of them targeting agriculture, the largest water user. These include increased irrigation efficiency, reconstruction of drainage systems, reuse of treated drainage water and introduction of water saving technologies (see annex 3).[117] However, water saving measures might also be introduced in other sectors, for instance through improved metering and pricing principles.

Awareness Raising

Communities affected by floods, drought or water quality problems can be assisted through measures with the objective to improve preparedness and self protection.[118] Awareness can be raised by the dissemination of knowledge through media and education.[119]

Development cooperation activities

Many donors, most of them multilateral are active in the Kura-Aras River Basin. Armenia for instance states that it has received financial assistance for the adaptation of water resources to climate change.[120] Most of these activities are related to improve transboundary cooperation and do not directly target climate change and adaptation. As explained above, cooperation among the basin countries is an essential precondition for establishing a joint research and monitoring platform on the impacts of climate change. In a next step, this would facilitate the identification of adaptation measures.

European Union

From June 2008 till the end of 2010, the European Union was active in the basin with the Transboundary River Management Phase II for the Kura River basin project. The purpose was to establish a transboundary monitoring and information management system and to improve the capacities of environmental and monitoring authorities with the long term objective of implementing an integrated water resources management approach. The project had five key components: (i) assessments and surveys, (ii) monitoring, (iii) management information and methodology, (iv) institutional capacity and training and (v) public engagement and civil society. Activities included joint field surveys in selected pilot areas in order to improve transboundary cooperation and identify and address data shortfalls. Joint monitoring programs.[121]

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[117] Republic of Azerbaijan 2000, p. 13
[118] UNDP 2007, p. 80
[119] World Bank 2009, p. 99
[120] Ministry of Nature Protection of the Republic of Armenia 2010, p. 58
[121] WaterWiki.net 2009a

German Financial Cooperation (KfW Entwicklungsbank)
Through KfW Entwicklungsbank, German Financial Cooperation is currently active in water and sanitation infrastructure projects in Armenia, Azerbaijan and Georgia; it also supports different transboundary projects to protect biodiversity.

A **transboundary project** on protecting biodiversity in the region among other things aims at reducing conflicts among Armenia, Azerbaijan and Georgia[122] in the framework of the Caucasus Initiative of the German Federal Ministry for Economic Cooperation and Development.[123] In March 2006, a conference with the Ministers of Environment of Armenia, Azerbaijan and Georgia took place in Berlin. During the conference, the establishment of the Caucasus Protected Area Fund with the objective to safe the protected areas in the three countries was announced.[124]

Armenia: Through KfW Entwicklungsbank, German Financial Cooperation is promoting investments in the water supply systems in the North Armenian provinces of Shirak and Lori. The objective of the programme in the towns of Armavir, Metsamor, Gyumri and Vanadzor and of villages and communities in the region, with together almost 330,000 inhabitants, is full continuity of water supply of adequate quality. So far, EUR 72 million have been made available. These funds support the three local water utilities which are in charge of the water supply improvement programme. The region still suffers from a major earthquake in the year 1988.[125]

Azerbaijan: KfW is assisting the Azerbaijani government in improving water and sanitation services in Ganja, the second largest town of the country and Sheki. This includes the rehabilitation and extension of networks and institutional consulting activities. The objective is to ensure water supply in reasonable quantity and quality. The total cost for the first phase of the program is expected to be about EUR 55 million, including an Azerbaijani commitment of EUR 7.6 million and a EUR 10 million grant of the Swiss State Secretariat for Economic Affairs.[126]

In **Georgia**, the focus of the KfW infrastructure program is at the Black Sea[127] and thus outside of the Kura-Aras drainage basin.

German Technical Cooperation (GIZ)
A project with the objective to protect biodiversity in Armenia, Azerbaijan and Georgia is currently implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). It aims at integrating an efficient and sustainable use of natural resources into the government sector as well as economy and society beyond limited conservation areas. Due to the differences between the South Caucasus countries, the approach is differentiated and is implemented at the country level. Beyond that, the project also promotes transboundary dialogue and exchange.[128]

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[122] KfW 2009a
[123] KfW 2009b
[124] KfW 2006
[125] KfW 2009d
[126] KfW 2009e
[127] KfW 2010
[128] GTZ 2010

UNDP

The UNDP “Regional Partnership for Prevention of Transboundary Degradation of the Kura-Aras River Project” is under implementation from 2008 to 2011. It covers Armenia, Azerbaijan and Georgia. The total cost of USD 2.9 Million is financed by the Global Environment Facility (GEF). The overall objective is to keep the quality and the quantity of the water in the basin adequate for the short and long-term needs of the ecosystem and its communities. Therefore, a draft Strategic Action Program will be prepared, setting foundations for a comprehensive and integrated long-term river management approach. This is followed by the implementation of the program through policy, institutional and legislative reforms at the regional and national level. Support is given to key pilot projects and the development of management tools. In order to facilitate a long term river management, sustainable financial and institutional arrangements are established. Key water polluting and withdrawing sectors will be reformed.[129]

The project was preceded by several others, among them the “Reducing Transboundary Degradation in the Kura/Aras River Basin Project”, which was implemented from 2005 to 2007 and had a total cost of USD 1.56 Million, financed by GEF, UNDP, national contributors and SIDA. Under the project, several national and regional reports were completed. A regional meeting was organized, bringing together experts from different countries, some of them meeting for the first time after the collapse of the Soviet Union.[130]

USAID

From 2004 to 2008, USAID implemented the South Caucasus Water Program. Again, the goal was to increase effective and sustainable regional cooperation concerning the management of shared water resources. The program had four specific objectives: (i) to strengthen the institutional framework, capacity for transboundary basin management and technical understanding, (ii) to develop the capacity to turn data into information, (iii) to strengthen civil society participation and (iv) to support the regional and international dialogue and cooperation on regional water management.[131]

Conclusions and recommendations

Even without climate change, the Kura-Aras river basin has been characterized by alternating geographical and climatic conditions among season and location. Floods are a common phenomenon in many areas. In order to regulate the flow, dams have been constructed with an additional function of withdrawing water, mainly for irrigation. Other direct anthropogenic interferences in the river flow include changes in land cover, flood protection measures and lining of river courses.

A lack of cooperation among the South Caucasus states and missing hydrological data on water quantity and quality, in particular concerning groundwater, are major obstacles to improved transboundary river management. Since the 1990s, several conflicts impede cooperation of the newly established states on water resources management. However, bilateral agreements on shared projects on the Aras River exist with Iran. In addition, many

[129] WaterWiki.net 2009b
[130] WaterWiki.net 2009c
[131] USAID 2006

formerly existing meteorological and hydrological stations ceased to work in the 1990s and even the existing data from USSR times are not easy to access, further impeding joint water management. As a downstream country, Azerbaijan is particularly vulnerable to the existing hazards concerning water quantity (floods and droughts) and quality and would profit most from cooperation. Donors including the European Union and UNDP have been very active in tackling the issue of cooperation. Transboundary cooperation through a multinational basin agency is an ambitious, but very useful goal.

The impacts of climate change are diverse. Increasing temperatures will lead to faster melting snow which feeds part of the rivers in the basin. This leads to increased peak flows in the summer months. In addition, the sea level of the Caspian Sea might increase or decrease considerably. With its coast, Azerbaijan is threatened by both developments. In areas which are already characterized by a dry climate, water availability is expected to decrease. A reduced flow has less dilution capacity, resulting in the additional impact of deteriorating water quality.

A wide range of adaptation measures is possible, ranging from no regret measures addressing water scarcity and quality issues to climate justified ones, targeting the uncertain development of the Caspian Sea level. It is recommended to concentrate on measures adapting to floods and droughts in the respective areas since they are much more likely to happen even without climate change. There is a large list of possible approaches, including among others research, infrastructural measures and awareness raising. Under the Caucasus Initiative of the German Federal Ministry for Economic Cooperation and Development, it is advised to include the important issue of transboundary cooperation. This might include the introduction of water protection areas and IWRM policies at the watershed level.

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Note: all electronic documents were accessed in September 2010

Annex

Annex 1: Map of Climate zones of the Caucasus ecoregion

Figure 12. Climate zones of the Caucasus ecoregion; source: UNEP and GRID-Arendal 2008

Annex 2: Climate change projections for selected locations

Salyan (Azerbaijan)					
Latitude and Longitude: 39.59/48.98					
Holdridge Zone: Warm temperate dry forest					
	Japanese High Resolution GCM	IPCC GCMs			
	Change (2091 - 2100 vs. 1981- 1990)	Change (2030 - 2049 vs. 1980-1999)	# Models Projecting Same Change	Country Average Values	Trend
Mean annual precipitation	8%	-3%	13/20	-4%	±
Runoff		-15%	1/12	-14%	-
Mean annual temperature (°C)	2	2		2	+
Daily precipitation intensity		5%	8/8	4%	+
Consecutive Dry Days	-19	4	6/8	4	+

Mingechevir (Azerbaijan)					
Latitude and Longitude:40.77/47.04					
Holdridge Zone: Warm temperate thorn scrub					
	Japanese High Resolution GCM	IPCC GCMs			
	Change (2091 - 2100 vs. 1981- 1990)	Change (2030 - 2049 vs. 1980-1999)	# Models Projecting Same Change	Country Average Values	Trend
Mean annual precipitation	16%	-5%	12/20	-4%	±
Runoff		-15%	1/12	-14%	-
Mean annual temperature (°C)	2	1		1	+
Daily precipitation intensity		4%	6/8	4%	+
Consecutive Dry Days	11	2	7/8	3	+

Tbilisi (Georgia)					
Latitude and Longitude: 41.69/44.78					
Holdridge Zone: Cool temperate steppe					
	Japanese High Resolution GCM	IPCC GCMs			
	Change (2091 - 2100 vs. 1981- 1990)	Change (2030 - 2049 vs. 1980-1999)	# Models Projecting Same Change	Country Average Values	Trend
Mean annual precipitation	18%	-5%	16/20	-4%	-
Runoff		-19%	1/12	-15%	-
Mean annual temperature (°C)	2	2		2	+
Daily precipitation intensity		4%	7/8	3%	+
Consecutive Dry Days	-1	4	6/8	5	+

Nakhichevani (Azerbaijan)

Latitude and Longitude: 39.07/45.41

Holdridge Zone: Cool temperate steppe

	Japanese High Resolution GCM	IPCC GCMs			
	Change (2091 - 2100 vs. 1981- 1990)	Change (2030 - 2049 vs. 1980-1999)	# Models Projecting Same Change	Country Average Values	Trend
Mean annual precipitation	25%	-5%	15/20	-4%	-
Runoff		-21%	0/12	-14%	-
Mean annual temperature (°C)	3	2		2	+
Daily precipitation intensity		5%	7/8	4%	+
Consecutive Dry Days	0	3	6/8	4	+

Yerevan (Armenia)

Latitude and Longitude: 40.16/44.48

Holdridge Zone: Cool temperate steppe

	Japanese High Resolution GCM	IPCC GCMs			
	Change (2091 - 2100 vs. 1981- 1990)	Change (2030 - 2049 vs. 1980-1999)	# Models Projecting Same Change	Country Average Values	Trend
Mean annual precipitation	25%	-8%	18/20	N.A.	-
Runoff		-21%	0/12	N.A.	-
Mean annual temperature (°C)	3	2		N.A.	+
Daily precipitation intensity		4%	7/8	N.A.	+
Consecutive Dry Days	7	5	7/8	N.A.	+

Maku (Iran)

Latitude and Longitude: 39.3/44.51

Holdridge Zone: Cool temperate steppe

	Japanese High Resolution GCM	IPCC GCMs			
	Change (2091 - 2100 vs. 1981- 1990)	Change (2030 - 2049 vs. 1980-1999)	# Models Projecting Same Change	Country Average Values	Trend
Mean annual precipitation	40%	-8%	18/20	-8%	-
Runoff		-23%	0/12	-16%	-
Mean annual temperature (°C)	3	2		2	+
Daily precipitation intensity		4%	7/8	7%	+
Consecutive Dry Days	-1	3	7/8	0	+

Kars (Turkey)					
Latitude and Longitude: 40.61/43.1					
Holdridge Zone: Cool temperate moist forest					
	Japanese High Resolution GCM	IPCC GCMs			
	Change (2091 - 2100 vs. 1981- 1990)	Change (2030 - 2049 vs. 1980-1999)	# Models Projecting Same Change	Country Average Values	Trend
Mean annual precipitation	21%	-5%	16/20	-8%	**-**
Runoff		-23%	0/12	-26%	**-**
Mean annual temperature (°C)	3	2		2	**+**
Daily precipitation intensity		4%	7/8	2%	**+**
Consecutive Dry Days	1	5	7/8	6	**+**

Table 8: Results of selected locations from the World Bank Climate Change Portal; source: World Bank 2010

Annex 3: Priority adaptation measures in the Southern Caucasus

Armenia. Second national communication of the Republic of Armenia under the United Nations Framework Convention on Climate Change (2010).	
Prepared by*: Ministry of Nature Protection of the Republic of Armenia; UNDP Office in Armenia; GEF*	
Project Number	Water Resources: Adaptation Measure:
Category: Accurate Assessment of Water Reserves	
1	Refurbishment of hydrological observation points with modern equipment (preferably automatic recording equipment) in order to improve the reliability of measurement and data management processes
2	Optimization of the network of hydrological observation stations, taking into account the principles of river basin management and the decision makers' need for data
3	Resumption of the measurements and monitoring of mudflows, water reserve in the snow and other characteristics of the snow
4	Resumption of the monitoring of groundwater, in order to obtain up to date data, as well as assess their vulnerability to climate change
5	Preparation of a new reference book for water resources, where the impacts of economic activity and global climate change on water bodies in recent years will be taken into account. It will also present the scientific justifications of data on rivers, lakes and water reservoirs, in the case of data availability in adequate detail and absence of data or their inadequacy
6	Preparation of water balance and water-economic balance for individual river basins, and preparation of hydrological maps based on the results, where all the main hydrological characteristics of water bodies in the country will be presented
7	Detailed studies for developing a modern methodology for calculating the natural flow based on the actual flow data, which will allow for accurate assessment of the volume of water return after the use for drinking, household, irrigation and industrial purposes
Category: Legal-organizational measures	
8	In order to reduce losses from leakages in drinking water supply and irrigation systems, develop legal, economic and administrative incentives
9	Initiate legislative changes contributing to the introduction of water saving technologies.
Category: Institutional measures	
10	Strengthen the monitoring, management and compliance assurance organizations; train personnel in collection and management of hydro-meteorological data, forecasts, monitoring, compliance assurance and control of permit conditions for water users; build the capacity of water users associations to improve irrigation systems and irrigation culture
11	Initiate investigation/studies to identify the relevant methods and tools for mitigating the vulnerability of water resources in Armenia.
Category: Technological measures	
12	Regulation of river flows, including increasing the volumes of current water reservoirs and/or building new ones
13	Reduction of losses from leakages in drinking and irrigation water supply systems
14	Application of advanced irrigation methods in agriculture (drip-subsurface irrigation, pivot irrigation, sprinkler irrigation, drip pipe irrigation, mole irrigation).
URL: http://unfccc.int/resource/docs/natc/armnc2e.pdf	

Azerbaijan. Initial national communication of Azerbaijan Republic under the United Nations Framework Convention on Climate Change (2000).		
Prepared by: *N.A.*		
Project Number	Project Title	Anticipated Project Cost (USD)
1	Construction of water reservoirs of complex destination and increase of efficiency of the existing water reservoirs on mountain rivers	305,500,000
2	Improvement of the water resources management system	12,000,000
3	Reconstruction of mains of channels and irrigation systems	N.A.
4	Use of water-saving technologies in water consumption system, introduction of update irrigation technologies	418,000,000
5	Afforestation and setting of anti-abrasion shelterbelts around the lakes and water reservoirs; shelterbelts along the rivers banks and the irrigation and collector-drainage network lines on the area of 13.8 thousand hectares	9,700,000
Total cost: 745,200,000		
URL: http://unfccc.int/resource/docs/natc/azenc1.pdf		

Georgia. Georgia's second national communication to the UNFCCC (2009).	
Prepared by: Ministry of Environment Protection and Natural Resources	
Project Number	Project Title
1	Creation in the Rioni Delta of a permanent monitoring and early warning system for observing the Black Sea level rise and storm intensity
2	Implementation of coast protection measures in the Rioni Delta
3	Carrying out of coast protection measures at the Adlia-Batumi section aimed at the protection of Batumi coastal zone
4	Preparation and implementation of the Lake Paliastomi adaptation measures
5	Rehabilitation of irrigation systems
6	Creation of flood monitoring and early warning system
7	Preparation of package of measures aimed at the reduction of casualties and losses caused by floods
8	Watering 900 ha of Taribana arable land
9	Planting of hazelnut in the Lentekhi region
10	Mitigation of disastrous glacial phenomena in the Dariali Gorge
URL: http://unfccc.int/resource/docs/natc/geonc2.pdf	

Table 9. Water related adaptation projects proposed under the national communications in Armenian, Azerbaijan and Georgia; source: UNFCCC 2010

Annex 4: Glossary of terms

This section provides definitions of the main frequently used terms concerning climate change adaptation.

Adaptation: is a process by which strategies to moderate, cope with, and take advantage of the consequences of climatic events are enhanced, developed, and implemented.[132]

Adaptive capacity: The ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.[133]

Climate change: Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.[134]

Climate variability: Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).[135]

Impacts are the detrimental and beneficial consequences of climate change on natural and human systems.[136]

Maladaptation: Any changes in natural or human systems that inadvertently increase vulnerability to climatic stimuli; an adaptation that does not succeed in reducing vulnerability but increases it instead.[137]

Resilience: Amount of change a system can undergo without changing state.[138]

Vulnerability: The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.[139]

Note: for more information concerning definitions, please refer to IPCC 2007b and OECD 2006.

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[132] UNDP 2005, p. 248
[133] IPCC 2001
[134] IPCC 2007b
[135] IPCC 2007b
[136] IPCC 2001
[137] IPCC 2001
[138] IPCC 2001
[139] IPCC 2001