Final Report on the environmental flow calculation in the Aragvi river

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1. Introduction: the Environmental Flow Assessment (EFA)

Environmental or ecological flows are the water that is left in a river ecosystem, or released into it, for the specific purpose of managing the condition of that ecosystem. The very final aim of Environmental Flow Assessment (EFA) is to improve the ecological conditions of a river (increase its "ecological status", according to the terminology of EU Water Framework Directive – WFD), by reducing the bad ecological effects of flow regime alteration.

Environmental flows alone are seldom a sufficient prescription for healthy rivers. Environmental flow allocations should be considered in combination with other complementary mitigation measures – such as water quality improvements or morphological restoration – in order to achieve a combination of management interventions able to bring the water body in "good ecological status". The present report, however, refers strictly to the environmental flow assessment of two pilot sub-basins of the Kura River and do not provide recommendations on other possible measures needed to reach the "good ecological status".

In 2018 the Aragvi river basin (left side tributary of the Kura river) was selected as pilot sub-basin in Georgia to test an EFA methodology. An experts' group including experts of different disciplines (hydrology, river morphology, ecology, water quality) was set up to monitor the rivers and assess the environmental flow following an "holistic approach". The river monitoring activity and the experimental ecological flow assessment of the Aragvi river was supervised by an international expert in river ecology.

With the term "holist approach" it was intended to apply an EFA not merely based on hydrological or hydraulic criteria but take into account the "needs" of the river biological community and those of the river morphology. An EFA methodology following an holistic approach have to consider three important points about environmental flows:

1. They are ecologically (or geomorphologically [habitat]) defined. They cannot be determined on the basis of hydrology alone.
1. They are not limited in scope to single species protection, but rather consider the entire river community as a whole.
2. They are not just minimum flows. They are *patterns* of flow events, or components, defined by their magnitude, frequency, duration, timing, and rate of change. The seasonal streamflow *patterns* shape natural habitats, provide cues for migration and spawning, distribute seeds and foster their growth, and enable rivers to function properly.

The "holistic" concept of environmental flows is clearly represented in the following picture. Light gray indicates natural hydrograph. Dark gray indicates amount of water needed in the river at different times of year to maintain healthy ecosystem function, indicated by numbers. All of the light gray is available for withdrawal. The dark gray can also be used by humans – for example for hydropower, navigation, downstream withdrawals, and even upstream withdrawals that return to the river instead of being consumed. The challenge is to manage water resources within a basin in order to achieve all targets, including environmental flows, water use, water quality, power production, etc. simultaneously.

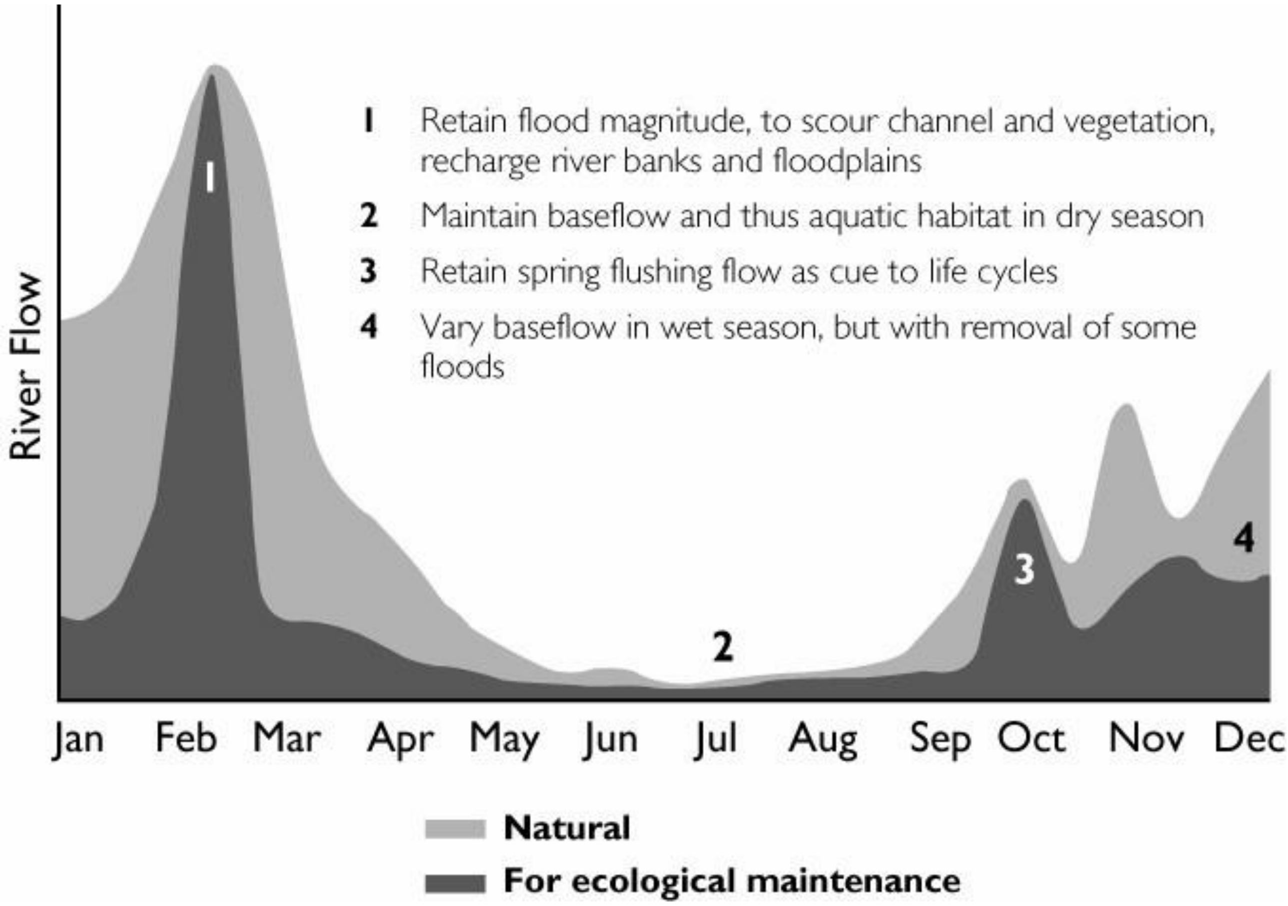


Figure 1 Example of an environmental flow recommendation/target/definition (Source: Tharme and King 1998)

A very wide scientific literature on "environmental flow assessment" was produced in the last 40 years; since the years 1990s most of them follow an holistic approach. Based on the existing worldwide experience in this field, in 2017 a group of international experts involved in a USAID technical assistance in Georgia developed an EFA holistic methodology for the rivers and streams of Georgia[1]. Such methodology proposes a very flexible approach that could be adopted in many geographical situations: that's why such EFA methodology has been used as a reference for the experimental EFA on the Aragvi river basin.

2. The Georgian institutional and legal framework for water abstraction and EFA

There are several major laws and numerous sublegal acts regulating the protection and management of water resources in Georgia. However, current water-related legislation is inconsistent and does not provide clear regulation of some important topics. Currently, Georgian legislation does not define the meaning and the method of calculation of environmental flow.

In the water law Georgia two major water use categories are identified: 'general' and 'special'. The 'general' category includes all uses which satisfy basic needs of the population, including bathing,

1 USAID 2017. The assessment of environmental flow for the rivers and streams of Georgia. Usaid governing for growth (g4g) in Georgia. Contract number: aid-114-c-14-00007. Deloitte consulting llp

swimming, recreational, and water for livestock. In Georgia, water for general use can be supplied from surface water and shallow and deep aquifers, if it is accessed without advanced facilities (i.e., pumps), avoiding effects on groundwater level and contamination. Otherwise, the water use falls into the ‘special’ category. In the country general water use is free of charge, without the need to become a ‘legal water user’ or obtain special permissions for natural resource use. The ‘special’ water-use category represents the use of water resources through advanced water supply and discharge facilities and it requires a legal permission by the Ministry of Environmental Protection and Agriculture of Georgia (MEPA). In the water law, the wastewater discharge is always in the special category.

Approximation of the existing Georgian legislation and standards to the EU and other international standards is needed. It would be mentioned that at the moment, Georgia is reforming its national environmental legislation and water protection sector. New draft law on “Water Resources Management” is drafted and presented to the Parliament of Georgia.

Generally, development and implementation of an overall policy in water resources management is the responsibility of the Ministry of Environmental Protection and Agriculture of Georgia (MEPA). Specifically, the ministry is in charge of developing legislation, conducting ecological expertise for environmental permitting, setting norms for water abstraction and wastewater discharge, collecting and processing statistical forms submitted annually by users of water resources (irrigation companies, hydroelectric and thermoelectric enterprises and industries), etc.

Legal Entity of Public Law LEPL National Environmental Agency (NEA) is responsible for the creation of monitoring systems that measure the quality and quantity of the surface and ground waters throughout the whole territory of Georgia.

Department of Environmental Supervision (DES) of MEPA controls implementation of the conditions of the permits and technical regulation set for surface waters.

3. The pilot sub-basin for the EFA determination

3.1 Characteristics of the physical (abiotic) and anthropogenic environment

The Aragvi River Basin, located in the North East part of Georgia (***Fig. 1***), belongs to the Mtkvari (Kura) River Basin. Administratively, the basin is located in the Mtskheta-Mtianeti region and is split between the Kazbegi (Origin of the river), Dusheti and Mtskheta (confluence to Mtkvari) municipalities. Tbilisi, the capital of Georgia, relies on water from this basin, but there are other water uses such as hydropower generation and irrigation drawing from the same water source. Throughout the last few decades, there has been a competition for water, and with a growing population this competition is expected to increase in the near future.

The river length is 112 kilometers, and the catchment area of the basin is 2,724 km^2. The Aragvi River is part of a river system integrated by the following main rivers: Mtiuleti (White) Aragvi (41 km), Gudamakari (Black) Aragvi (30 km), Khevsureti Aragvi and Pshavis Aragvi (56 km) (***Fig. 2***). The Aragvi River is a main part of this river system and originates in the Northeastern part of the volcanic mountain referred as Keli. In the upper and middle sections, the Aragvi River is a typical mountain river, but in the lower part it flows in Mukhran-Saguramo valley and has features resembling a river valley. Near the city of Mtsketa, Aragvi River flows into River Mtkvari (Kura).

Jinvali reservoir, which is an artificial reservoir, divides the basin into an upper and a lower section, modifying the hydrologic regime of the river. The majority of water resource consumers are located in downstream of Jinvali reservoir, in the lower reaches of Aragvi River. Water from Aragvi River is used for irrigation, water supply to the city of Tbilisi and is the main source of water for local settlements and small manufactures.

Another important feature of the Aragvi River Basin is the Zhinvali hydropower dam. The Zhinvali hydropower dam is one of the largest dams of Georgia, is 102-meters high and generates 130 MW hydro-electric power. It was constructed in 1986 and forms the Jinvali Reservoir.

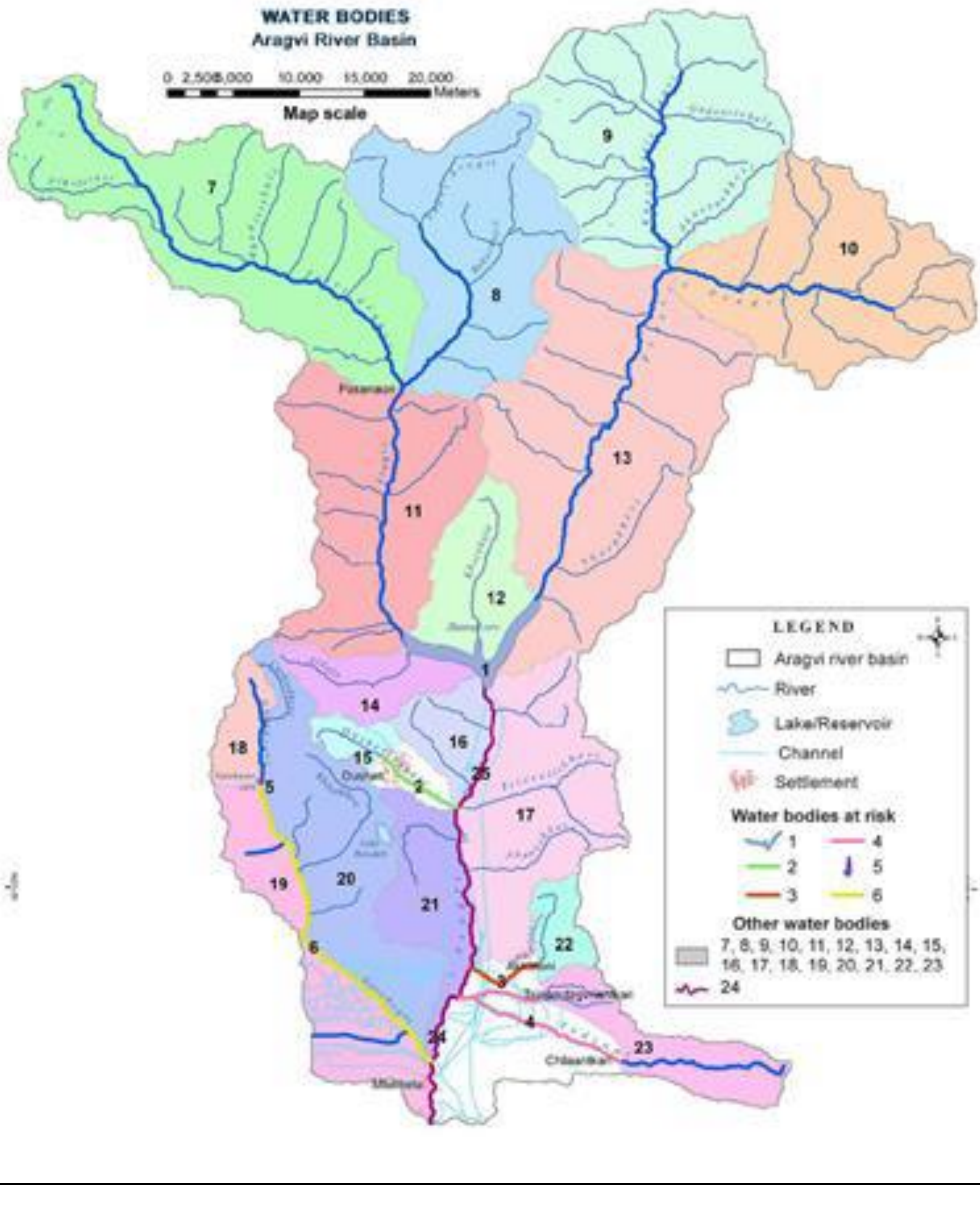


Figure 1. Map of Aragvi river basin in Georgia

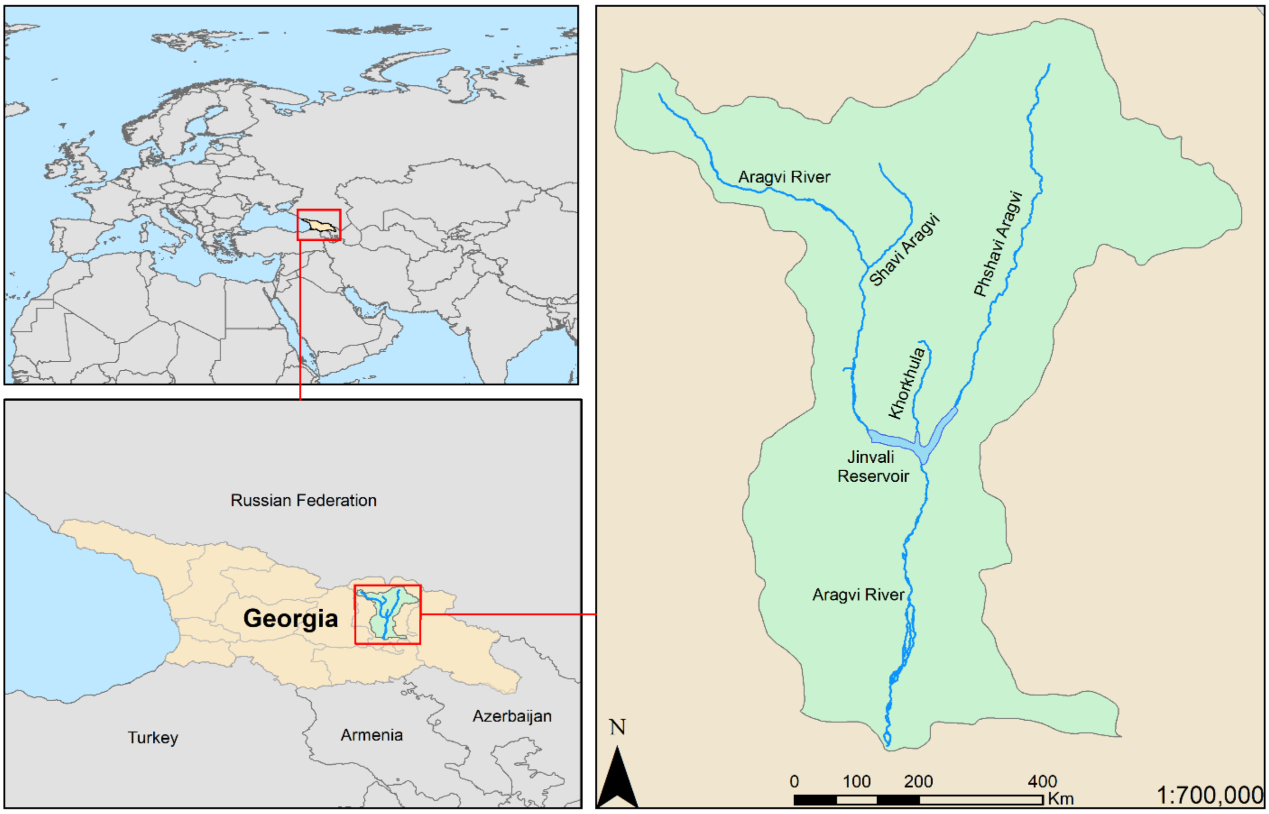


Figure 2. Main tributaries of the Aragvi River

The main rivers in the basin are: Tetri (white) Aragvi; Shavi (black) Aragvi (joining the Tetri Aragvi in Pasanauri); Pshavis Aragvi (joining the Tetri Aragvi in the Zhinvali reservoir); downstream Zhinvali the river is called simply Aragvi; Narekvavi (joining the Aragvi few km upstream Mtskheta, where the Aragvi flows into the Kura).

In the basin of river Aragvi there are many rivers under label Aragvi, especially noteworthy for their size are Mtiuleti (White), Gudamakari (Black), Pshavi and Khevsureti Aragvis. Black Aragvi flows into White Aragvi near Pasanauri, and Khevsureti Aragvi into Pshavi Aragvi – near village of Udzilaurta. Pshavi and Mtiuleti Aragvi converge into a single river and flow into Mtkvari near Mtskheta.

River Aragvi is characterized by diverse regime of feeding. At its source it gets nourishment from waters of melting snow, in the middle body it gets its feed from melting snow and rain waters, and in the lower flow – from rain and underground waters. Its waters are used by Tbilisi residents, Zhinvali water basin and hydro power plants, Tbilisi water pool (sea), Aragvi gorge settlements and irrigated territories. Aragvi gorge is distinguished with unique sceneries. It is the most important recreational region for Tbilisi dwellers and guests. Within a very short distance here and in a short time span it is possible to visit assorted natural and ethnographic attractions.

The Aragvi River Basin upstream of Jinvali consists of two main branches, an eastern and a western branch. The western basin can be divided into two drainage sub-basins as there are the

White Aragvi (Tetri Aragvi) and the Black Aragvi (Shavi Aragvi). The eastern branch is called Pshavi Aragvi. Most of the catchment area is covered by forest. In the vicinity of the main settlements forests have been logged as a result of firewood cutting. The Aragvi branches are highly dynamic mountainous streams with high flow velocity, unstable substrata, and a high load of coarse sediments. Close to the Jinvali dam the valleys of the main branches widen and the river morphology is characterised by anastomoses and wandering meanders.

The river banks mainly show pristine riparian vegetation, except in stretches where the river banks are stabilized to protect roads, bridges or transmission lines. Besides these hydraulic structures, there is also some impact on the river morphology caused by gravel mining activities (large number of gravel pits). However, the main environmental impact in the lower part of the basin is caused by the Jinvali dam where at low water levels a mighty layer of fine sediment is revealed. Old gauging stations exist but have not been in operation for the last 20 years. Also a few small hydropower stations existed (installed in the 1930s to 1950s) but have already been abandoned in the 1970s. Close to settlements some waste and litter can be found in the river; sewage is dumped in sinks. Industry in the basin seems to be undeveloped, only small food processing facilities can be found.

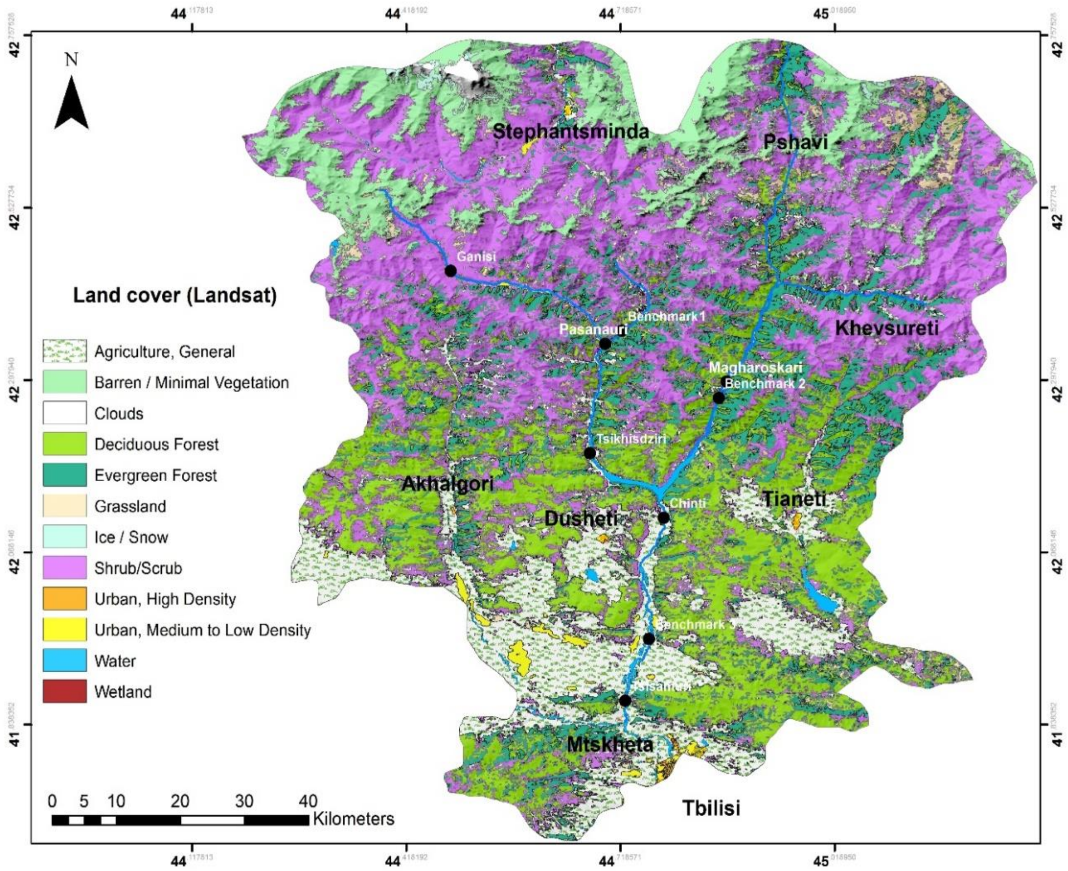


Figure 3. Land cover types distributed along the Aragvi river basin. The black spots on the map (Fig. 3 and Fig. 4) indicate six major sites of the field survey selected within the project and three benchmark sites related to the major sites for the comparative study of the biodiversity (see ch. 3.2)

Level of agricultural impact on the riparian habitats is equally high for the territories of the project interest (***Fig. 3***).

As it is shown on the map (Fig. 3), agricultural lands cover large areas in the Aragvi river valley and are most intense along the river basin. The map is based on the landsat data of European Space Agency (ESA) portal and displays land cover information assessed for the year of 2000 (Bontemps et al., 2013; Santoro et al., 2017. SNCMR, 2020).

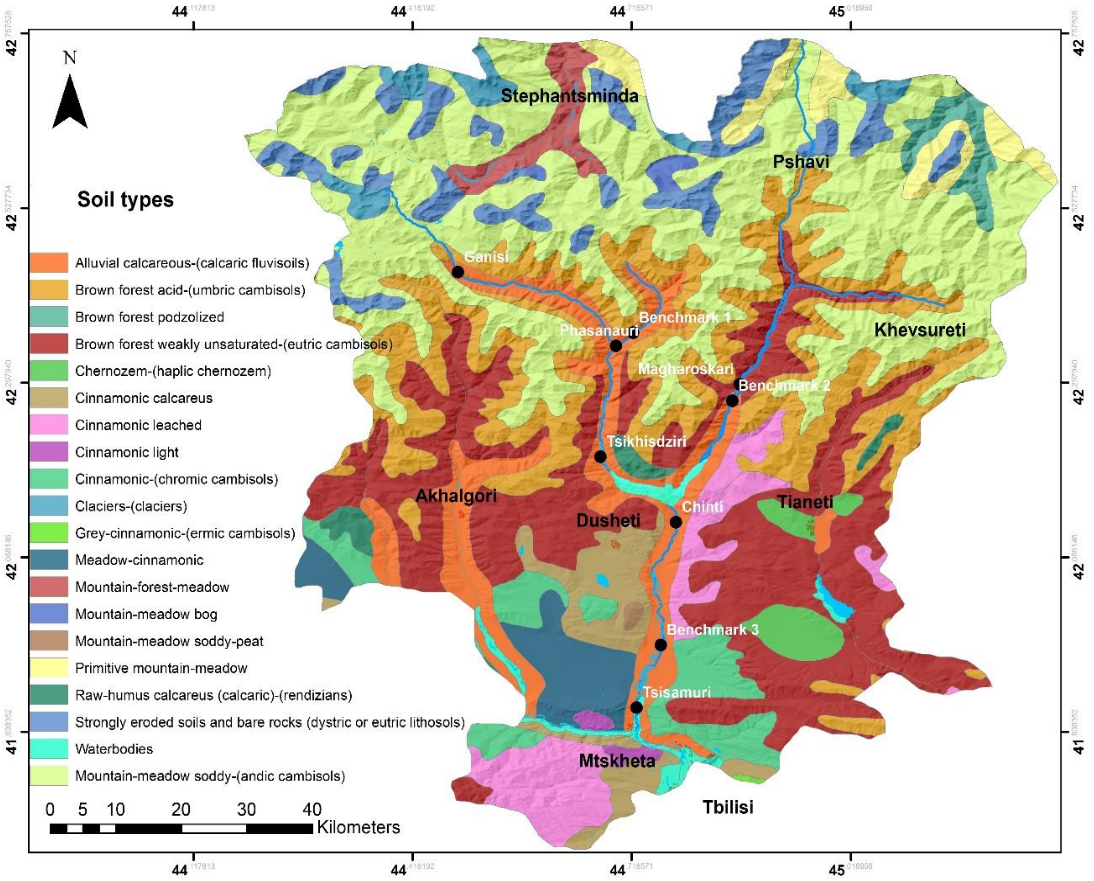


Figure 4. Soil types distributed along the Aragvi river basin.

Aluvial calcareous soil or Calcaric fluvisol is the dominant soil type along the Aragvi river basin (Fig. 4) [Urushadze, 1997; WRB, 2006]. Soil type changes into the Eutric cambisols in the basins of the Pshavi and Khevsureti streams of the river Aragvi. This one of the variations of the brown forest soils which occurs on the area of origin of the river streams conditioned by the replacement of the riparian habitats by the mountain forests. In overal, figures 4 and 5 provide scheme of the diversity of soils in the Aragvi river valley and their sustainability against the erosion.

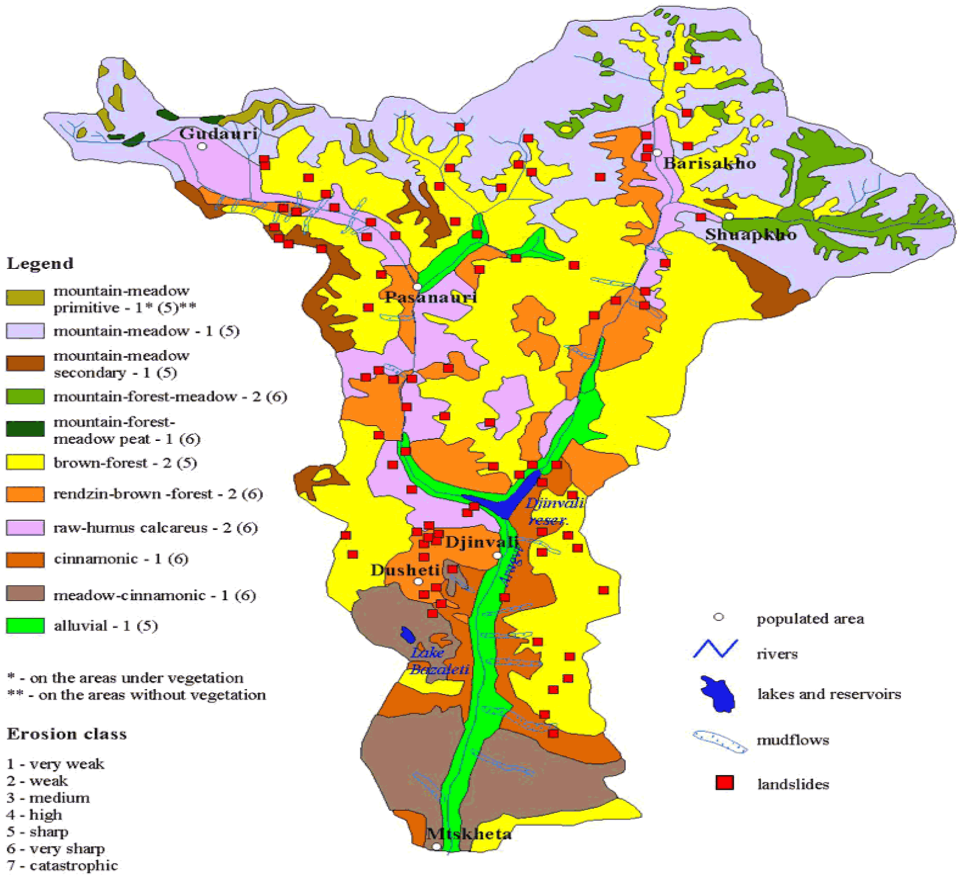


Figure 5. Soils sustainability against erosion in the Aragvi River Basin

Region is tectonically active. It is crossed by two seismic sub-zones of Kazbegi-Lagodekhi and Zone of the central uplift. According the classification of seismicity of the territory of Georgia (Bondyrev, Davitashvili & Singh, 2015) which includes four major zones and 24 subzones, seismic sub-zones covering the region of Mtskheta-Mtianeti are characterized with moderately high seismicity. One of the most important geohazards associated with Aragvi river gorge is mudflow and landslides. In the past 15-10-year period heavy landslides occurred in village Makarta (Gudamakari valley, Black Aragvi gorge, 2010 y) and in the village Mleta (White Aragvi gorge, 2014).

Climate in Aragvi river valley is quite variable and diverse. Indicators of average air temperature in July hover from +10 to +23°C, and in January – from 0 to 10°C, the volume of precipitation swings from 1800 mm to 500 mm. In its catchment area there are 7 types of landscapes that increase perceptional and esthetic value of the gorge. Climate diagrams display climatic character of the settlements arranged on the bottom (Mtskheta), middle (Pasanauri) and top locations of the project territory (Fig. 6).

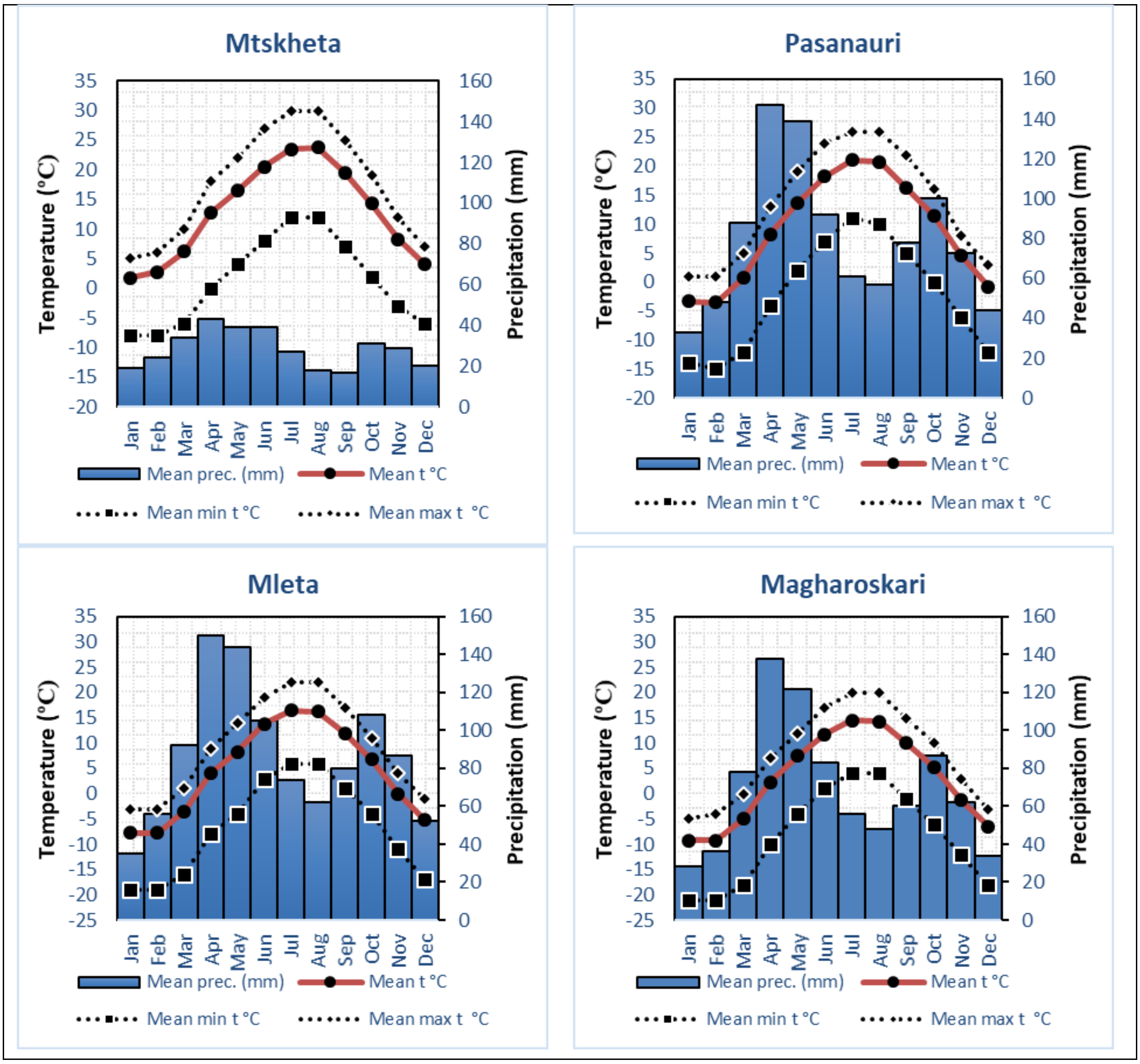


Figure 6. Basic character of the climate along the transect of the project research territory

Major climate factors such as mean annual temperature and mean annual precipitation varies dependently on altitude on the project territory (Fig. 7). As it is shown on Figure 7, Temperature significantly decreases (R^2=0.922; P<0.001) while precipitation increases (R^2=0.849; P<0.001) along the altitudinal gradient within the project territory.

Downstream of the Jinvali Reservoir the Aragvi River is characterised by low bed slope and wide cross sections with large flood plains. Flow is regulated by the Jinvali Reservoir and water is extracted for irrigation purposes and supply of drinking water (separate reservoir). Some of the existing diversion structures and weirs might also be suitable locations for run- of-river hydropower plants (hydraulic head of 4 to 8 m). Upstream of the Jinvali Reservoir the Aragvi River Basin can be divided into an eastern part and a western part of similar size. In the eastern part the river shows a number of narrow and steep sections (especially in the upper part) which would allow for construction of weirs or intake structures. As the road is always close to the river, some road relocation might be required. The type of (small) hydropower facility suitable for this part of the catchment would be some kind of low to medium-head scheme with only small reservoirs which allow for effective sediment flushing.

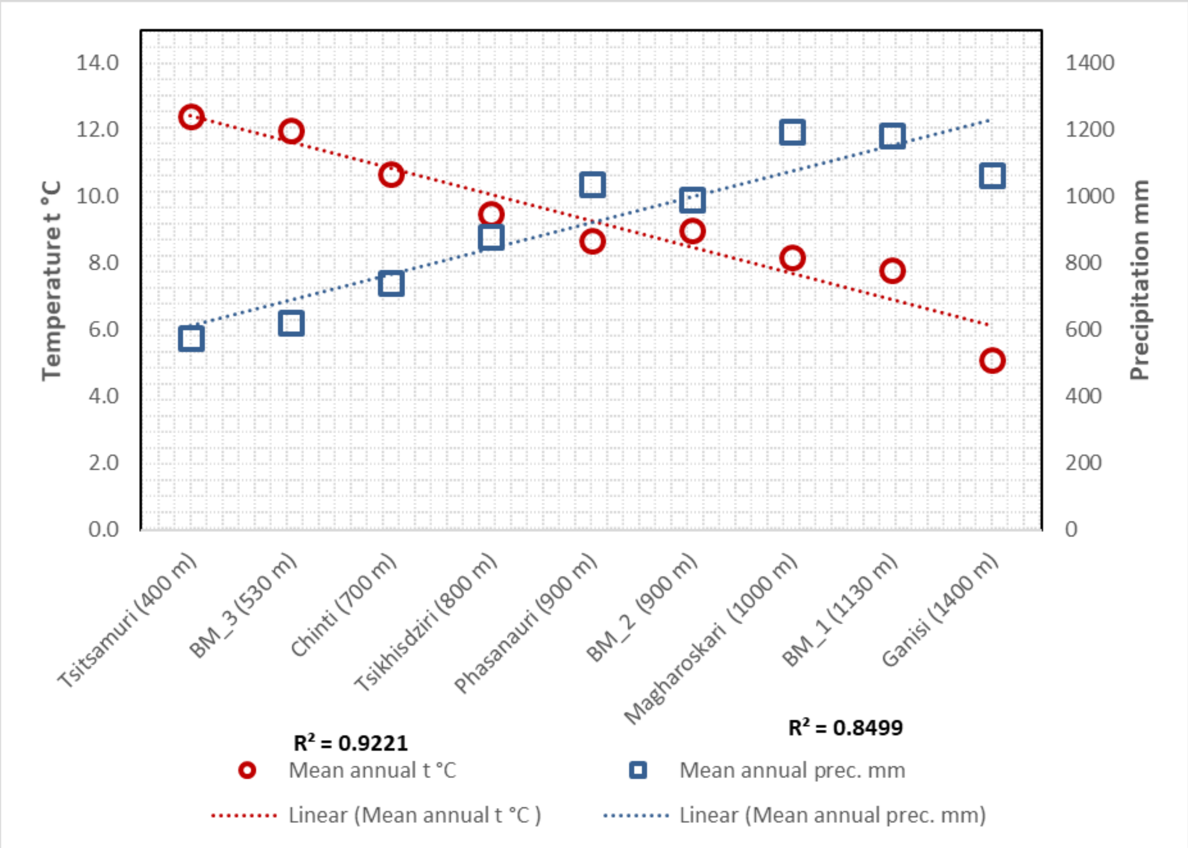


Figure 7. Distribution of mean annual temperature °C (Bio1) and mean annual precipitation (Bio12) along the project research territory (Data source: worldclim.org).

The western part of the basin has two main tributaries: The Black and the White Aragvi Rivers. The river morphology is less favourable for hydropower development in the lower parts of White Aragvi. Here the river valley is wide and large amounts of sediments are received from the lateral tributaries. There is obviously also a serious landslide problem.

However, in the upper parts and in the Black Aragvi River Basin, a number of suitable locations with more favourable cross section geometry and less sediments have been identified. A number of artesian wells can be found in both sub-basins indicating the complex geological situation along the side slopes and in the valley bottoms. Significant hydropower potential also exists in some of the side valleys (lateral tributaries) due to the large head available. However, access to these side valleys might be difficult, especially during the wintertime.

In General, human population density is low in the western and eastern part of the basin. The major part of the settlements is concentrated along the Aragvi river on the adjacent territories of the river basin. The region of Mtskheta-Mtianeti is formed by four municipalities of Dusheti, Tianeti, Mtskheta and Kazbegi (also known as Khevi). Mtskheta is the largest municipality in the region. Major body of the Aragvi river lies on the territories of the municipalities of Mtskheta and Dusheti.

Table 1. Human population of the municipalities of Mtsketa-Mtianeti

Municipalities of the region	Census of 2002	Census of 2014	Census of 2016	Census of 2017	Census of 2018
Dusheti	33,636	25,659	25,900	26,000	26,100
Tianeti	14,014	9,468	9,800	9,900	10,000
Mtskheta	64,829	55,651	54,400	54,200	53,900
Kazbegi	5,261	3,795	3,800	3,800	3,800
Total (Mtsketa-Tianeti)	117,740	94,573	94,100	93,900	93,900

According the data of The National Statistics Office of Georgia, Population of the region has decreased by 20 % in the region during the last 10 years (Tab. 1). The migration rate was highest from the municipalities of Dusheti and Mtsketa. Ashough the direct data is not available, it is also plausible that with a migration of the local people the amount of the livestock has also decreased as the livestock holding is the major agricultural activity in the region. During the last 15-10 years, region become active in terms of implementation of infrastructural projects: several hydropower plants (four new objects in total in the village Dzegvi, Dariali valley, Aragvi valley [Aragvi 2 HPP] and Gudauri) were constructed and/or are in process of the construction; “JSC Georgian State Electrosystem (GSE)” implements the project of “Kazbegi Interconnection Project - 500 kV Ksani-Stepantsminda Transmission Line (KSTL)” which crosses the significant part of the Aragvi river valley; Energopro Georgia ltd. constructed freshwater reservoirs on the downstream of the Aragvi river. Natakhtari; In 2019-2020 the stretch of Natakhtari-Zhinvali road of the ‘Militari Road’ of Georgia located in the Mtskheta-Mtianeti region was reconstructed. Recently the project of the construction of a 23-km Kvesheti-Kobi bypass road has also started which will cross the upper streams of the river. These are few mentions of the ongoing and planed infrastructural activities in the region which indicates that the anthropogenic impact has modified in the last 15-10 years but retained as the major factor of the degradation of the natural environment and disturbance of the biodiversity on the Kura II project target territory.

3.2 Sites selected for the monitoring in Aragvi river basin in the framework of the Kura II project

Six basic sites were selected for the monitoring of the floodplain and riparian biotic and abiotic environments to cover all major water bodies of the Aragvi river (Tab. 2).

Table 2. The list and locations of the monitoring sites of the Kura II project in the Aragvi river gorge

Location	Latitude	Longitude	Altitude m a.s.l
1. Mtiuleti (White Aragvi) [Municipality of Dusheti]	42.29593	44.86719	900
2. Gudamakari (Black Aragvi) [Municipality of Dusheti]	42.29433	44.86181	915
3. Magharoskari (Municipality of Dusheti)	42.3464	44.69699	1000
4. Tsikhisdziri (Municipality of Dusheti)	42.20039	44.67586	800
5. Chinti (Municipality of Dusheti)	42.11425	44.77906	700

6. Tsisamuri (Municipality of Mtskheta)	41.8706	44.72524	400
Benchmark 1 (Gudamakari valley, Municipality of Dusheti)	42.27426	44.8564	900
Benchmark 2 (near v. Magharoskari Municipality of Dusheti)	42.36377	44.72043	1130
Benchmark 3 (near v. Misaktsieli, Municipality of Mtskheta)	41.95284	44.75846	530
Ganisi (Municipality of Kazbegi) [reference site]	42.44348	44.48049	1400

Basic sites were used to monitor the monthly and annual dynamics of both biotic and abiotic components of the environment. On three localities areas with well-developed natural vegetation of the riparian habitats, located in the neighbouring areas to the basic sites of the monitoring, were also included in the study in purpose to compare floristic and faunistic diversity of the extremely degraded and relatively natural habitats. Reference site of Ganisi located in the basin of white Aragvi (in surroundings of the v. Ganisi) was used for the comparison of the biodiversity between the natural habitat types.

3.3 Characteristic of the biological environment

Territory of the Aragvi river basin framed by the project area is dominated by the two major types of the natural habitats. According the classification of European Nature Information System (EUNIS) [Davies, Moss and Hill, 2004; Abdaladze & Batsatsashvili, 2007], these habitats are 1) riparian floodplain and gallery woodlands (EUNIS code G1.2) characterized by mixtures of woody species such as Alnus, Fraxinus, Populus, Quercus, Ulmus, Salix (Fig. 5 A) and 2) boreo-alpine riparian galleries (EUNIS code G1.12.) [Fig. 5 B,C], predominantly by one of the variation of this habitat: G1.127. Ponto-Caucasian montane alder galleries: Riverside and lakeside alder galleries and cordons of the Pontic Range and the Caucasus system, with *Alnus subcordata, A. barbata* or *Alnus incana*.

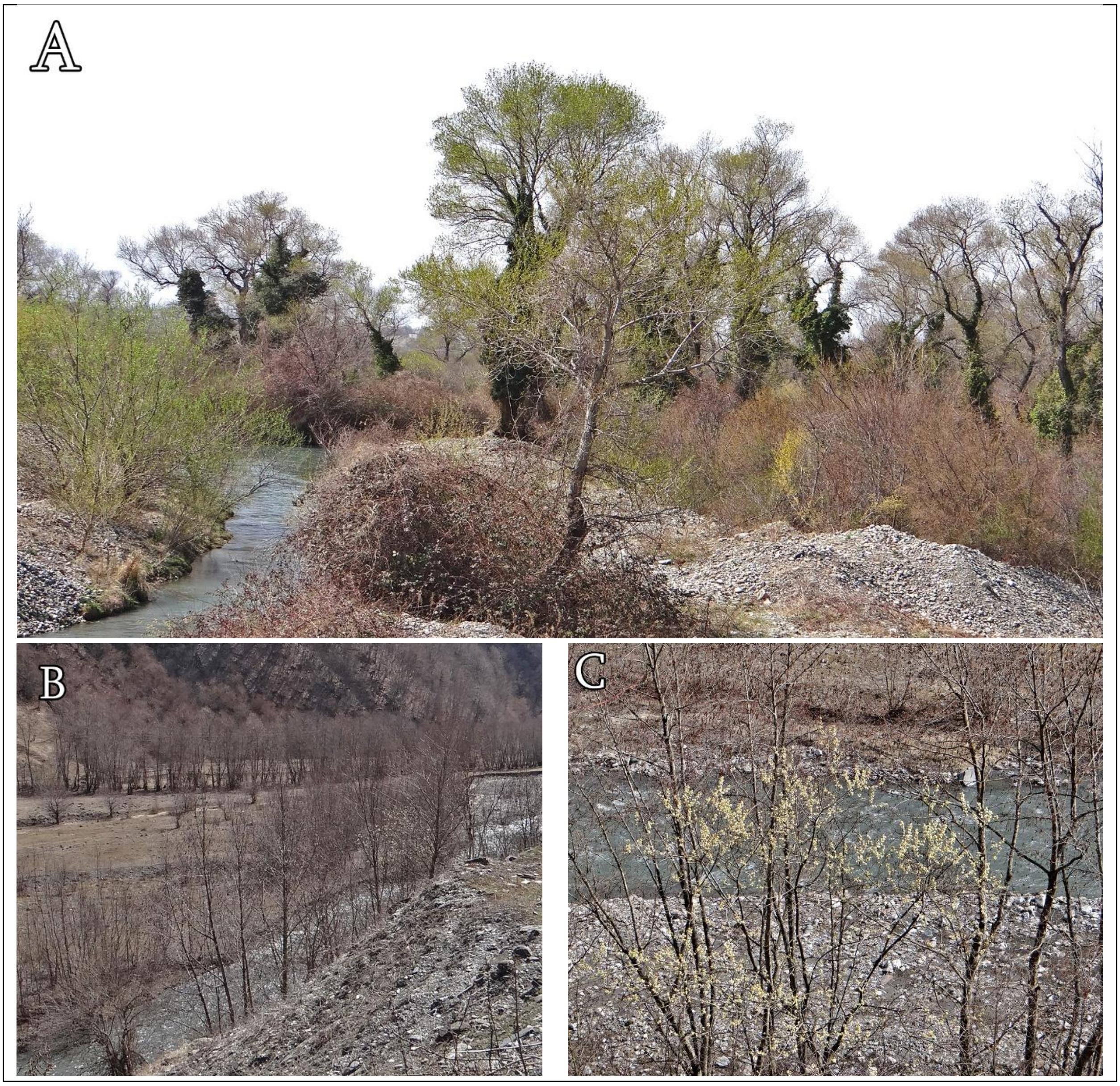


Figure 5. Benchmark sites: A) Benchmark site №1 (near v. Bakhani, Gudamakari valley); B) Benchmark site №2 (near v. Tsiprani, Magharoskari team); Benchmark site №3 (near v. Misaktsieli, Mtskheta).

Riparian floodplain and gallery woodlands are distributed on the downstream areas of the Aragvi river. Boreo-alpine riparian galleries are well developed on the referenced site of v. Ganisi surroundings and benchmarked site №1 (near v. Bakhani, Gudamakari valley).

Table below (Tab 3.) provides information on the distribution of the floristic and faunistic diversity on the monitoring and referenced sites selected for the study within the project. Faunistic data are partly based on literature sources concerned with the diversity of faunal groups in the Aragvi river valley. Detailed description of this data is provided in the baseline study of the sites selected for the monitoring within Kura II project (Asanidze, 2019, a.). Floristic data are field survey based and provide precise indication of the diversity of the several taxonomic groups of the plants and liverworts on the monitoring and reference sites. Diversity of the algae are also literature based (Barinova and Kukhaleishvili, 2014). Detailed description of this data is provided in the final report of the first stage of the Kura II project (Asanidze, 22/04/2020). The term 'Taxonomic diversity' in the table (Tab. 3) is equivalent to the species richness and indicates the number of species of the indicated group of the life organisms on each studied and monitored sites. With the distribution of the diversity, the table also provides information on the vegetation cover on each site. This character was measured using the specific methodology on the sites (Asanidze, 2019, a.), however the table (Tab 3.) shows averaged data for each site.

Table 3. Distribution of the floristic and faunistic diversity on the project territory (basic sites of monitoring) and referenced sites (benchmark [BM] sites and site of v. Ganisi located in the upstream area of the Aragvi river)

Altitudinal distribution of the sites and taxonomic groups of flora and fauna	Tsisamuri	BM_3	Chinti	Tsikhisdziri	Mtiuleti	BM_1	Magharoskari	BM_2	Ganisi
Altitude (m a.s.l.)	400	530	700	800	900	900	1000	1130	1400
Woody species cover (%)	14.17	49.95	7.77	10.1	8.65	23.61	4.95	21.96	8.42
Herb cover (%)	41	35	62	70	51	46	55	48	42
Taxonomical diversity of Cyanobacteria (Algal flora)	38	38	38	42	24	24	70	70	35
Taxonomical diversity of Heterokontophyta (Algal flora)	168	168	168	91	125	125	163	163	181
Taxonomical diversity of Euglenophyta (Algal flora)	3	3	3	10	0	0	2	2	5
Taxonomical diversity of Chlorophyta (Algal flora)	25	25	25	36	13	13	18	18	24
Taxonomical diversity of Charophyta (Algal flora)	76	76	76	19	36	36	34	34	44
Taxonomical diversity of Fishes	19	18	17	14	8	9	10	12	12
Taxonomical diversity of Insect	14	30	19	23	15	29	23	29	24
Taxonomical diversity of Large mammals	0	3	2	3	2	2	6	2	2
Taxonomical diversity Rodents	3	7	12	9	9	9	13	9	9
Taxonomical diversity Bats	4	8	7	8	7	4	4	4	4
Taxonomical diversity Birds	42	49	46	51	54	55	38	29	52
Taxonomical diversity Reptiles	8	10	8	8	8	7	8	9	7
Taxonomical diversity Amphibians	4	5	3	5	1	2	2	2	2
Taxonomical diversity Cryptogams	5	9	8	6	6	10	11	12	9
Taxonomical diversity Woody species	26	30	22	26	15	18	11	16	9
Taxonomical diversity Grass species	8	6	6	9	8	4	8	5	5
Taxonomical diversity Sedge species	4	5	4	5	5	1	4	4	3
Taxonomical diversity Legume species	3	1	3	7	7	1	9	2	9
Taxonomical diversity Herb species	45	35	46	69	55	27	55	19	61

Natural habitats are extremely degraded on the project territory and occur in form of small patches of the riparian vegetation and few elements of such vegetation. Degradation of the natural riparian habitats become the reason of selecting the additional localities with higher quality stands of the riparian forests as a benchmark sites for comparative study of the floristic and faunistic diversity.
On the basic sites (1-6, Tab. 2) riparian habitats are extremely degraded and replaced by the urban habitats identified as a type of Regularly or recently cultivated agricultural, horticultural and domestic habitats (EUNIS category of J). Sub-habitats of this category are rich in rural, naturalised and/or invasive species of flora and fauna associated with anthropogenic lands.

Table 4 provides the simplified scheme which visualizes ecological conditions on the monitoring sites based on the comparison of the state of the diversity of the floristic and faunistic groups and vegetation cover with the referenced sites (three benchmark sites and the site of the v. Ganisi provided in Tab 3).

Table 4. Ecological conditions of the monitoring (basic) sites of the Kura II project in respect of the diversity of the floristic and faunistic components.

	Tsisamuri	**Chinti**	**Tsikhisdziri**	**Mtiuleti**	**Magharoskari**	**Ganisi**
Woody species cover (%)	Poor	Bad	Bad	Poor	Poor	Poor
Herb cover (%)	Good	Moderate	Moderate	Good	Good	High
Taxonomical diversity of Cyanobacteria (Algal flora)	High	High	High	High	High	High
Taxonomical diversity of Heterokontophyta (Algal flora)	High	High	High	High	High	High
Taxonomical diversity of Euglenophyta (Algal flora)	Poor	Poor	Bad	High	Good	Good
Taxonomical diversity of Chlorophyta (Algal flora)	High	High	High	High	High	High
Taxonomical diversity of Charophyta (Algal flora)	High	High	High	High	High	High
Taxonomical diversity of Fishes	High	High	High	Poor	Moderate	Moderate
Taxonomical diversity of Insect	Moderate	Good	High	Moderate	Good	Good
Taxonomical diversity of Large mammals	Bad	Moderate	Moderate	Moderate	High	Moderate
Taxonomical diversity Rodents	Poor	High	Good	Good	High	Good
Taxonomical diversity Bats	Moderate	High	High	High	Moderate	Moderate
Taxonomical diversity Birds	Good	Good	High	Good	Good	Good
Taxonomical diversity Reptiles	Good	Good	Good	Good	Good	Good
Taxonomical diversity Amphibians	Good	Good	Good	Poor	Moderate	Moderate
Taxonomical diversity Cryptogams	Moderate	Good	Moderate	Moderate	High	Good
Taxonomical diversity Woody species	Good	Good	Good	Poor	Bad	Bad
Taxonomical diversity Grass species	Moderate	Good	Moderate	Poor	Poor	Good

Taxonomical diversity Sedge species	Good	Good	Good	Moderat e	Moderate	Moderat e
Taxonomical diversity Legume species	Moderate	Moderat e	Moderate	Moderat e	Poor	Poor
Taxonomical diversity Herb species	Poor	Poor	Bad	Poor	Poor	Bad
Bioclimate conditions	Good	Good	Good	Good	Good	Good
Agricultural impact	Poor	Bad	Bad	Bad	Bad	Poor
Human population density	Bad	Moderat e	Moderate	Bad	Good	Good
Geohazard risks	Good	Good	Good	Moderat e	Bad	Bad
Overall state of the diversity	Good	Good	Good	Moderat e	Poor	Poor

Aragvi river valley is used by migratory birds as a corridor for the seasonal migrations. The diversity of the large mammals, rodents, herpetofauna and insects is associated with mountain forests located in the distant areas from the riparian habitats of the major body of the Aragvi river in this river valley. Due to the anthropogenic impact and the character of the altitudinal distribution of the life zones in the valley, endemicity and diversity of flora and fauna is significantly higher on the areas of the upper streams of the Aragvi than on the downstream of the river. The data provided in the baseline and midterm reports of the floristic and faunistic study and monitoring of the project sites show that the endemism of plants and animals increases on the high altitudes of the Aragvi river basin. The data provided in the midterm report (Asanidze, 26/9/2019) are more specific and precise for plant species monitored on the project sites. These data show that the endemism on the plants significantly increases in the upstream areas of the Aragvi river basin (Fig. 6). The majority of the endemic species are distributed on the monitoring site of the v. Magharoskari and reference site of the v. Ganisi.

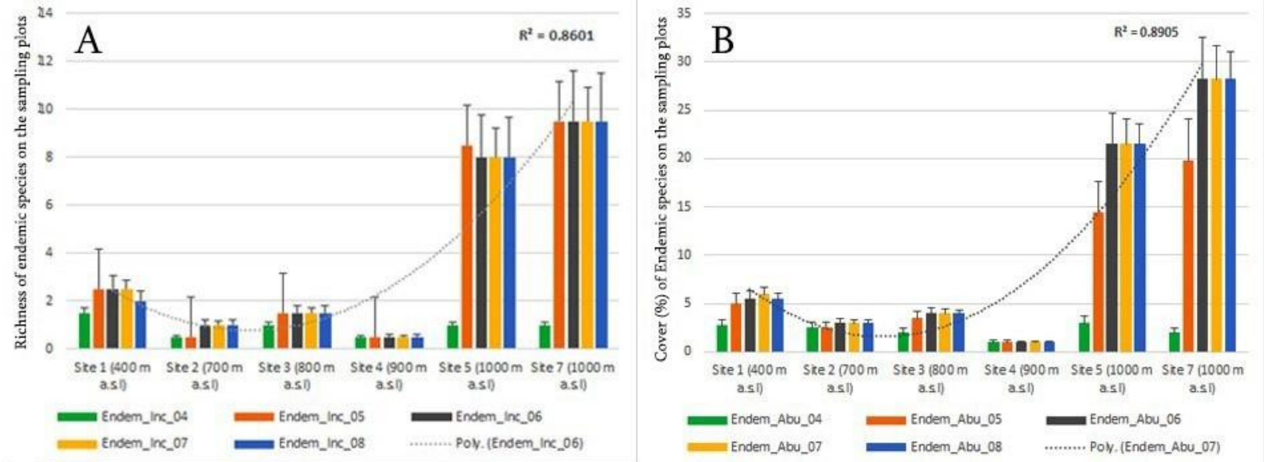


Figure 6. The scheme provides the state of richness (section A) and abundance (Section B) of the endemic plants on the the monitoring sites of: 1. Tsisamuri (Municipality of Mtskheta), 2. Chinti (Municipality of Dusheti), 3. Tsikhisdziri (Municipality of Dusheti) 5. Magharoskari (Municipality of Dusheti) and 7. Ganisi during the basic season of the monitoring (from April to August).

Land use is quite diverse on the project territory. Arable lands and village gardens with their irrigation channels are merging the river basin and taking water source from the major body of the river or its streams. Aragvi river also takes contamination from the sewerage of the local villages. Irregular network of sewerage is not equipped with filters which would avoid the direct flow of the polluted wastewater in the river. The other direct anthropogenic factors causing the disturbance and erosion of the diversity of the riparian habitats are wood logging, irregular grazing; uncontrolled fishing and hunting; gravel extraction / mining and etc.; Zhinvali Hydropower Plant artificially regulates flow regime of Aragvi river the negative effect of which is the deterioration of the natural flow regime of the river and cause seasonal crisis in the water supply to the floodplain habitats. Local road network formed by the major and the secondary roads is extremely intense along the Aragvi river gorge. This gorge hosts one of the strategically oldest and important roads of Georgia also called as a 'Military road' which connects the country to the North Caucasus (Russian Federation). Enumerated factors make it obvious that the level of the disturbance of the local biodiversity and the degradation of the riparian habitats is significantly high on the project territory.

4. Characterisation of each water body

4.1 Mtiuleti (White Aragvi)

The river body is a long stretch of mountain river running in a narrow valley limited by the mountain sides or locally by ancient terraces. The whole river corridor is mostly occupied by a large gravel high flow riverbed, with few small patches of floodplain. Water flow is mainly wandering with short stretches of braided flow, where the valley is wide enough. Several villages along the Valley are located by the river. An important road runs beside the river on its right bank and several stretches of river ar interested by roads on both banks.

Physico-chemical elements

The water quality appears to be very good with the only exception of NH_4 concentration, that is anomalously high, considering the possible source of pollution (untreated sewage of small mountain villages) and the average monthly flow (ranging between 6 and 24 m^3/s). In this water body the water quality could be classified in high state.

Physico-chemical elements			
	Average	min	max
Dissolved Oxygen, mg/L	10.69	9.50	13.10

BOD5 (mg/L)	1.30	0.93	2.14
COD (mg/L)	3.32	2.23	4.80
NH_4 (mg/L)	0.25	0.20	0.35
NO_3 (mg/L)	0.61	0.13	2.45
Phosphate (PO_4-), mg/L	0.11	0.05	0.15

Benthic invertebrates

For the sampling site Pasanauri on the river White Aragvi, the sample was taken on spring season. These below mentioned macroinvertebrates appeared into biological analyses*: Atherix sp., Baetis sp., Chloroperlidae Gen. sp., Chironomidae Gen. sp., Epeorus sp., Glossiphoniidae Gen. sp., Goeridae Gen. sp., Hexatoma sp., Hydrachnidae Gen. sp., Hydropsyche sp., Leuctra sp., Nemoura sp., Perla sp., Rhithrogena sp., Rhyacophila sp., Simuliidae Gen. sp., Sericostoma sp.* Based on this information ecological status is high (nEQR 1.00) for the sampling site.

Glacial fast mountain White Aragvi river, close to natural conditions could be classified as a river with high ecological status. Nevertheless, according to the calculation the sample taken in March, 2019 has high ecological status.

Based on this information, on the flow data and on the general conditions of the riverbed the water body could be classified in high state.

Hydromorphological elements

The morphology of the riverbed is slightly altered by the presence of roads (continuosly on the right bank; frequent on the left bank) and by a few bank defences in correspondence of bridges and of the villages by the river. However the flow is presently undisturbed, the relationships with most of the floodplain and the sediment transportation function still preserved. The WB could be classified in good state.

Sinthesis: classification of the water body

The classification of the three quality elements ranges between the high state of the physic-chemical elements and the good state of the benthic invertebrates and of the hydromorphological elements. **The Mtiuleti water body could be classified in good state**.

Characteristics of the vegetation

According to the results of the monitoring, sprouting phase of the herbaceous vegetation starts in the beginning of April. The most active phase of blooming starts in the second half of June and lasts to the end of July. The second part of July is the period when the floristic diversity reaches its maximum. The phase of senescence and the beginning of dormancy starts in the second decade of October. Seasonal variability of the floristic diversity is moderate as the overall increase (and decrease) of the species richness of the plants on the monitoring plots is 22% of the total richness of the plots. Annual variability of the floristic diversity is extremely low as it remined unchanged on the monitoring site during the period of the monitoring. Rural habitat type is dominant on the site of Mtiuleti and forms 80% of the floodplain vegetation. Accordingly, the floristic elements of the natural riparian habitats cover 20% of the site area.

The dominant plant species on this site are:
Trees, shrubs and lianas: *Populus hybrida, Tamarix ramosissima, Salix alba, S. caprea;*
Grasses and sedges: Anthoxanthum odoratum, Deschampsia cespitosa, Setaria pumila, Poa bulbosa, Carex atrata, Carex hirta, Carex cespitosa Carex contigua.
Legumes: *Medicago lupulina, Melilotus albus, Trifolium ambiguum, Trifolium medium.*
Echium vulgare, Euphrasia hirtella, Lythrum salicaria, Mentha aquatica, Perilla nankinensis, Pulicaria dysenterica, Pycreus flavescens,
Herbs: *Echium vulgare, Euphrasia hirtella, Lythrum salicaria, Mentha aquatica, Perilla nankinensis, Pulicaria dysenterica, Pycreus flavescens, Hieracium macrolepis, Lapsana communis , Leontodon hispidus, Myosotis alpestris, Ranunculus oreophilus Potentilla erecta, Solanum nigrum, Urtica dioica, Viola arvensis.*

4.2 Gudamakari (Black Aragvi)

The river runs in a narrow valley limited by steep mountain sides. The whole river corridor is mostly occupied by a large gravel high flow riverbed, with few small patches of floodplain. Water flow is mainly wandering with short stretches of braided flow, where the valley is wide enough. Several villages along the Valley are located by the river, but roads are not located in the valley but along the mountainside. Some temporary roads into the riverbed could be observed by the Satellite view.

Physico-chemical elements

The water quality appears to be very good with the only exception of NH_4 concentration, that is anomalously high, considering the possible source of pollution (untreated sewage of small mountain villages) and the average monthly flow (ranging between 2 and 17 m^3/s). In this water body the water quality could be classified in high state.

Physico-chemical elements			
	Average	min	max
Dissolved Oxygen, mg/L	10.40	10.01	11.70
BOD5 (mg/L)	1.70	0.80	3.09
COD (mg/L)	2.88	1.70	4.12

NH_4 (mg/L)	0.28	0.22	0.31
NO_3 (mg/L)	0.58	0.18	2.27
Phosphate (PO_4-), mg/L	0.07	0.04	0.13

Benthic invertebrates

For the sampling site Pasanauri on the river Black Aragvi samples were taken 2 times on the spring season. These macroinvertebrates appeared into biological analyses: Atherix sp., Baetis sp., Chironomidae Gen. sp., Chloroperlidae Gen. sp., Chrysops sp., *Ecdyonurus sp., Epeorus sp., Goeridae Gen. sp., Hexatoma sp., Hydropsyche sp., Leuctra sp., Nemoura sp., Perla sp., Perlodidae Gen. sp., Rhithrogena sp., Sericostoma sp.;* Based on this information ecological status were calculated for each sampling site. Generally, as an average result (0.94) High ESCS received.

Before the calculated result, based on the hypothesis and the preliminary information, the river type has been identified as the glacial fast mountain river, close to natural conditions with high ecological status.

Based on this (very preliminary) information, on the flow data and on the general conditions of the riverbed <u>the water body could be classified in high ecological state</u>.

Hydromorphological elements

The morphology of the riverbed appears nearly undisturbed. The road on the right bank runs mainly on the mountainside and only in few stretches in the floodplain. A few small defence could be detected, but most part of the river runs free of any alteration. The flow is presently natural. <u>The WB could be classified in high state</u>.

Sinthesis: classification of the water body

The classification of the three quality elements ranges between the high state of the physic-chemical elements and of the hydromorphological elements, and the good state of the benthic invertebrates. **<u>The Gudamakari water body could be classified in high state</u>**.

Characteristics of the vegetation

Vegetation on Gudamakari site is similar to the site of Mtiulety as the distance between these sites is very small (about 200 m), however there is small difference in floristic diversity. sprouting phase of the herbaceous vegetation starts in the beginning of April. The most active phase of blooming starts in the second half of June and lasts to the end of July. The second part of July is the period when the floristic diversity reaches its maximum. The phase of senescence and the beginning of dormancy starts in the second decade of October. Seasonal variability of the floristic diversity is moderate as the overall increase (and decrease) of the species richness of the plants on the monitoring plots is 20% of the total richness of the plots. Annual variability of the floristic diversity is extremely low as it remined unchanged on the monitoring site during the period of the monitoring. Rural habitat type is dominant on the site of Gudamakari and also forms 80% of the floodplain vegetation. Accordingly, the floristic elements of the natural riparian habitats cover 20% of the site area.

The dominant plant species on this site are:

Trees and shrubs: Populus hybrida, Tamarix ramosissima, Salix alba;

Grasses and sedges: *Anthoxanthum odoratum, Dactylis glomerate, Deschampsia cespitosa, Setaria pumila, Poa bulbosa, Carex atrata, Carex hirta, Carex cespitosa Carex contigua.*
Legumes: *Medicago lupulina, Trifolium ambiguum, Trifolium medium.*
Herbs: *Echium vulgare, Euphrasia hirtella, Lythrum salicaria, Mentha aquatica, Perilla nankinensis, Pulicaria dysenterica, Pycreus flavescens, Hieracium macrolepis, Lapsana communis , Leontodon hispidus, Senecio grandidentatus, Myosotis alpestris, Ranunculus caucasicus, R. oreophilus, Potentilla erecta, Solanum nigrum, Urtica dioica, Viola arvensis.*
Endemic plants: *Rubus caucasicus, Chaerophyllum humile, Heracleum leskovii, Centaurea transcaucasica, Cirsium obvallatum, Campanula alliariifolia, Geranium gymnocaulon, Teucrium nuchense.*

There is a benchmark site (Benchmark site №1) selected in Gudamakari valley for the comparative study of the habitat structure and vegetation diversity. This site is 20 % richer in plant species than Gudamakari monitoring site and 18% richer than Mtiuleti site. Woody plants cover 40% larger area in overall than on the sites of Gudamakari and Mtiuleti. Occurrence of the phenological development phases of the vegetation on this benchmark site is similar to the monitoring sites of Gudamakari and Mtiuleti as these three sites are arranged closer to each other altitudinally. Reason of the better development of the natural riparian habitat on benchmark site is smaller amount of the human population on its locality.

Additional site for comparison of the vegetation diversity and to cover larger diapason of the habitats was selected in surroundings of the v. Ganisi. Boreo-alpine riparian galleries are dominated on this locality which differs with its vegetation from the rest of the sites selected for the project study, however small components of the riparian vegetation of this site is shared by the monitoring and benchmark (Benchmark №1) sites of Gudamakari valley. On Ganisi site, sprouting phase of the herbaceous vegetation starts in the Second decade of April. The most active phase of blooming starts in the last decade of June and lasts to the end of July. The second part of July is the period when the floristic diversity reaches its maximum. One of the specificities of this site is the higher diversity of the endemic plant species which exceeds at last twice in richness to the diversity of such group of plants distributed on the sites of Gudamakari valley which are also rich in endemic plant species.

Dominant species in the vegetation of the Ganisi site are:
Trees, *shrubs and semi shrubs: Alnus glutinosa, Corylus avellane, Cornus mas, Hippophae rhamnoides, Rosa canina, Salix caprea, Tamarix ramosissima, Sambucus ebulus, Anthoxanthum odoratum, Calamagrostis glauca, Poa pratensis, Phleum pratense, Carex cespitosa, Carex contigua, Carex rostrata, Luzula spicata;*
Legumes: *Medicago glutinosa, Medicago hemicycle, Trifolium ambiguum, Trifolium alpestre, Vicia alpestris;*
Herbs: *Chaerophyllum roseum, Achillea millefolium, Erigeron annuus, Astrantia maxima, Carduus onopordioides, Centaurea cheiranthifolia, Leontodon hispidus, Petasites albus, Taraxacum confusum, Tripleurospermum inodorum, Hesperis matronalis, Sisymbrium loeselii, Campanula latifolia, Minuartia circassica, Stellaria graminea, Solidago virgaurea, Cruciata laevipes, Dactylorhiza euxina, Dictamnus caucasicus, Epilobium hirsutum, Euphrasia georgica, Galium rubioides, Geranium gymnocaulon, Lythrum salicaria, Prunella vulgaris, Salvia glutinosa, Solanum nigrum, Sparganium erectum, Teucrium nuchense, Thymus collinus, Typha latifolia, Urtica dioica,*

Verbascum thapsus, Veronica gentianoides, Veronica telephiifolia, Viola odorata, Viola somchetica;

Endemic plant species: *Chaerophyllum roseum, Heracleum sosnowskyi, Astrantia maxima, Carduus onopordioides, Pyrethrum chamaemelifolium, Senecio sosnovskyi, Taraxacum confusum, Erysimum szowitsianum, Hesperis matronalis, Minuartia circassica, Silene linearifolia, Scabiosa caucasica, Astragalus denudatus, Astragalus oreades, Coronilla balansae, Lotus caucasicus, Medicago glutinosa, Medicago hemicycle, Vicia alpestris, Geranium gymnocaulon, Thymus collinus, Dactylorhiza euxina, Anemone fasciculata, Potentilla elatior, Euphrasia georgica, Viola somchetica;*

4.3 Tsikhisdziri

In this section the Aragvi river runs out of the narrow mountain valley and its riverbed widen progressively to reach nearly 500 m. Most of the river corridor is still occupied by the gravel bed but significantly portions of floodplain appear, partly vegetated, partly occupied by settlements and human infrastructures. The large gravel riverbed appears sometimes to be altered by human activity.


Physico-chemical elements

The water quality appears to be very good with the only exception of NH_4 concentration, that is anomalously high, considering the possible source of pollution (untreated sewage of small mountain villages) and the flow recorded during the monitoring activity (ranging between 10 and 37 m^3/s). In this water body the water quality could be classified in high state.

Physico-chemical elements			
	Average	min	max
Dissolved Oxygen, mg/L	11.02	9.52	14.70
BOD5 (mg/L)	1.57	0.81	2.99
COD (mg/L)	2.90	2.03	3.95
NH_4 (mg/L)	0.27	0.13	0.32
NO_3 (mg/L)	0.41	0.01	1.41

Phosphate (PO_4-), mg/L	0.19	0.08	0.32

Benthic invertebrates
For the sampling site Tsikhisdziri on the river Aragvi, samples were taken 4 times on winter, spring and summer seasons. Macroinvertebrates mentioned below appeared into biological analyses: *Atherix sp., Bezzia sp., Ceratopogonidae Gen. sp., Chironomidae Gen. sp., Chrysops sp., Dicranota sp., Ecdyonurus sp., Epeorus sp., Ephemerella sp., Goeridae Gen. sp., Hexatoma sp., Hydropsyche sp., Leuctra sp., Lymnaeidae Gen. sp., Perla sp., Psychomyia sp., Rhithrogena sp., Rhyacophila sp., Sericostomatidae Gen. sp., Simuliidae Gen. sp., Simulium sp.;* Based on this information ecological status were calculated for each sampling site and generally, as an average result (0.9175) High ESCS received.

Generally, the river Aragvi Tsikhisdziri type has been identified as a medium-sized fast river between mountains with a high ecological status.

Considering the fact that four samples were taken on winter, spring and summer seasons, three out of four has a high ecological status except the third sample taken on May 25th, 2019.

Based on this information, on the flow data and on the general conditions of the riverbed the water body could be classified in high state.

Hydromorphological elements
The Aragvi river at this section presents conditions for a potential high state: the river is still mostly completely free to move laterally in the large riverbed and the relationships with the floodplain and the sediment transport functions are well preserved. However the riverbed appears to be altered by gravel relocation and probably unregulated gravel mining. Large solid wastes and concrete blocks could be found in the riverbed. The water body could be classified in moderate state.

Sinthesis: classification of the water body
The classification of the three quality elements ranges between the high state of the physico-chemical elements and the moderate state of the hydromorphological elements. **The Tsikhisdziri water body could be classified in moderate state**.

Characteristics of the vegetation
According to the results of the monitoring, sprouting phase of the herbaceous vegetation also starts in the beginning of April on Tsikhisdziri site. The most active phase of blooming starts in the second half of June and lasts to the end of July. The second part of July is the period when the floristic diversity reaches its maximum. The phase of senescence and the beginning of dormancy starts in the second decade of October. Seasonal variability of the floristic diversity is low as the overall increase (and decrease) of the species richness of the plants on the monitoring plots is 10% of the total richness of the plots. Annual variability of the floristic diversity is extremely low as it remined unchanged on the monitoring site during the period of the monitoring.
Rural habitat type covers quite large area of the site of Tsikhisdziri and forms 65% of the floodplain vegetation. Accordingly, the floristic elements of the natural riparian habitats cover 35% of the site area. Specificity of this and other monitoring sites located in the downstream area of Aragvi river

are occurrence of higher abundance of the rural and invasive plant species such as Ambrosia artemisifolia which forms large populations in the riparian habitats.

Dominant species of the vegetation of the Tsikhisdziri monitoring site are:
Trees, shrubs, semi shrubs and lianas: *Acer campestre, Hedera helix, Periploca graeca, Berberis vulgaris, Alnus glutinosa, Carpinus orientalis, Lonicera orientalis, Clematis vitalba, Cornus mas, Cornus sanguinea subsp. australis (syn. Swida australis), Elaeagnus angustifolia, Fraxinus excelsior, Malus domestica, Prunus cerasifera, Prunus spinosa, Prunus incana, Rosa canina, Rubus caesius, Salix alba, Salix caprea, Populus × canescens, Tamarix ramosissima, Ulmus glabra;*
Grasses and sedges: *Anthoxanthum odoratum, Dactylis glomerate, Briza media, Calamagrostis arundinacea, Calamagrostis glauca, Deschampsia cespitosa, Poa pratensis, Setaria pumila, Phleum pretense, Carex atherodes, Carex atrata, Carex rostrata, Cyperus fuscus, Eleocharis palustris, Luzula spicata;*
Legumes: *Medicago glutinosa, Trifolium ambiguum, Trifolium alpestre, Trifolium medium, Vicia sepium;*
Herbs: *Aegopodium podagraria, Leucanthemum vulgare, Peucedanum tauricum, Torilis arvensis Asparagus verticillatus, Sonchus asper, Cicerbita racemosa, Cichorium intybus, Erigeron annuus, Ambrosia artemisiifolia , Arctium lappa, Cirsium arvense, Eupatorium cannabinum, Lapsana communis, Xanthium strumarium, etc*. (see Anex 1, B)

4.4 Magaroskhari (Pshavis Aragvi)

This mountain water body runs in a narrow valley. Its riverbed is mostly confined by the mountainside but, were the valley it's larger, takes a braided shape with islands and naturally vegetated floodplain.

Physico-chemical elements

The water quality appears to be very good with the only exception of NH_4 concentration, that is anomalously high, considering the possible source of pollution (untreated sewage of small mountain villages) and the flow recorded during the monitoring activity (ranging between 6 and 48 m^3/s). In this water body the water quality <u>could be classified in high state</u>.

Physico-chemical elements			
	Average	min	max
Dissolved Oxygen, mg/L	9.82	9.20	10.70
BOD5 (mg/L)	1.19	0.84	1.77
COD (mg/L)	2.75	1.22	4.05
NH_4 (mg/L)	0.28	0.17	0.33
NO_3 (mg/L)	0.61	0.19	2.25
Phosphate (PO_4-), mg/L	0.12	0.04	0.17

Benthic invertebrates

For the sampling site Magharoskari on the river Pshavis Aragvi, samples were taken 2 times on the spring season. These macroinvertebrates appeared into biological analyses: Atherix sp., *Baetis sp., Chironomidae Gen. sp., Dicranota sp., Epeorus sp Goeridae Gen. sp., Hexatoma sp., Hydropsyche sp., Leuctra sp., Nemoura sp., Perla sp., Perlodidae Gen. sp., Rhithrogena sp., Rhyacophila sp., Sericostoma sp., Simuliidae Gen. sp., Simulium sp.;* Based on this information ecological status were calculated for both sampling site. Generally, as an average result (0.9) High ESCS received.

Generally, the river Pshavis Aragvi Magharoskari type has been identified as a glacial fast mountain White Aragvi river, close to natural conditions could be classified as a river with high ecological status.

Considering the fact that two samples were taken at the same season, the first has high ecological status and second sample has good. According to the calculations,

Based on this information, on the flow data and on the general conditions of the riverbed the water body could be classified in good state.

Hydromorphological elements

The morphology of the riverbed appears nearly undisturbed. The road on the right bank runs mainly on the mountainside and only in few stretches in the floodplain. Most part of the river runs free of any alteration. The flow is presently natural. The WB could be classified in high state.

Sinthesis: classification of the water body

The classification of the three quality elements ranges between the high state of the physico-chemical elements and of the hydromorphological elements, and the good state of the benthic invertebrates. **The Magaroskhari water body could be classified in good state**.

Characteristics of the vegetation

According to the results of the monitoring, sprouting phase of the herbaceous vegetation starts in the beginning of April. The most active phase of blooming starts in the second half of June and lasts to the end of July. The second part of July is the period when the floristic diversity reaches its maximum. The phase of senescence and the beginning of dormancy starts in the second decade of October. Seasonal variability of the floristic diversity is low as the overall increase (and decrease) of the species richness of the plants on the monitoring plots is 6% of the total richness of the plots. Annual variability of the floristic diversity is extremely low as it remined unchanged on the monitoring site during the period of the monitoring. Rural habitat type covers approximately half of the land area of the site of Magharoskari. Accordingly, the floristic elements of the natural riparian habitats cover 50% of the site area.

Dominant species of the vegetation of the Magharoskari monitoring site are:

Trees, shrubs, semi shrubs and lianas: *Acer campestre, Alnus glutinosa, Corylus avellane, Clematis vitalba, Cornus mas Prunus cerasifera, Rosa canina, Salix caprea, Populus tremula, Tamarix ramosissima, Sambucus ebulus*.
Grasses and sedges: *Dactylis glomerate, Calamagrostis glauca, Lolium perenne, Poa pratensis, Setaria pumila, Phleum pretense, Carex atrata, C. flava, C. sylvatica, Pycreus flavescens, Juncus tenageia, Luzula spicata*.
Legumes: *Medicago glutinosa, Trifolium ambiguum, Trifolium alpestre, Trifolium medium, Vicia sepium;*
Herbs: *Astrodaucus orientalis, Leucanthemum vulgare, Cynanchum acutum, Sonchus asper, Cichorium intybus, Tussilago farfara, Arctium lappa, Cirsium arvense, Eupatorium cannabinum, Lapsana communis, Taraxacum grossheimii, Xanthium strumarium, Alyssum alyssoides, Rorippa sylvestris, Campanula rapunculoides, Stellaria media, Oberna multifida, Anthyllis variegate, Gentianella caucasea, Geranium pretense, Glechoma hederacea, Prunella vulgaris, Salvia glutinosa, Stachys palustris, Lythrum salicaria, Bistorta carnea, Rumex acetosella, Primula vulgaris, Ranunculus oreophilus, Alchemilla xanthochlora, Potentilla erecta, Euphrasia hirtella, Urtica dioica*.

In Pshavis Aragvi valley, there is a second benchmark site selected (Benchmark site №2) for comparison with Magharoskari site which is located near to this monitoring site. On the benchmark site 2, woody plant species cover 40% larger area than on monitoring site of Gudamakari. Species richness is almost similar in number to the neighboring benchmark site, however on the benchmark site 2 there is higher number of the plant species which are typical for the natural riparian habitats. Phenological cycles of the vegetation is similar in timing for the benchmark and monitoring sites located on the upstream areas of the Aragvi river as they are more or less closely arranged to each other altitudinally. Richness of the endemic plant species on the benchmark and monitoring sites of Magharoskari is lower than on the sites of the black and white Aragvi streams (see annex 1, Part A).

4.5 Chinti (downstream Zhinvali water reservoir)

The Zhinvali dam is located where the valley become narrow. A few Km downstream, the valley opens again and the Aragvi riverbed presents a wandering shape, with short stretches were the bed is braided, with a few vegetated island. The floodplain (quite large on the right bank) is colonized by natural vegetation in small patches, but is for large extension used for farming or pastures, and partly occupied by residential and industrial buildings. Around 10 Km downstream the dam, the riverbed has been heavily narrowed and the surrounding areas are occupied by a series of ponds and reservoirs.


Physico-chemical elements

Although the monitoring station is located downstream Zhinvali water reservoir, the water quality doesn't appear significantly changed compared to the monitoring stations located upstream the dam. All the oxygen related parameters are very good (according to them the water quality could be considered high). NH_4 concentration, is still anomalously high, but this recurring anomaly suggest a possible measurement error. The nutrients concentrations are slightly higher than upstream the dam but still compatible with good water quality. In this water body the water quality <u>could be classified in good state</u>.

Physico-chemical elements			
	Average	min	max
Dissolved Oxygen, mg/L	10.65	9.30	12.30
BOD5 (mg/L)	1.27	0.84	1.95
COD (mg/L)	2.87	1.88	4.70
NH_4 (mg/L)	0.30	0.25	0.35
NO_3 (mg/L)	0.41	0.03	1.23
Phosphate (PO_4-), mg/L	0.13	0.05	0.23

Benthic invertebrates

For the sampling site Chinti on the river Aragvi, samples were taken 4 times in different seasons. Mainly these macroinvertebrates appeared into biological analyses: *Baetis sp., Chironomidae Gen. sp., Chrysops sp., Dicranota sp., Ecdyonurus sp., Elmis sp., Empididae Gen. sp, Ephemera sp., Gomphidae Gen. sp., Hexatoma sp., Hydrachnidae Gen. sp., Hydropsyche sp., Hydroptila* *sp., Leuctra sp., Limnius sp., Prionocera sp., Psychomyia sp., Rhithrogena sp., Rhyacophila sp., Simulium sp.;* Based on this information ecological status were calculated for each sampling site and generally, as an average result (0.835) High ESCS received.

Before the calculated results, based on the hypothesis and preliminary information, the river type has been identified as a regulated river between mountains with a high ecological status.

Considering the fact that 4 samples were taken on four different seasonal times, three out of four has a high ecological status except third sample taken on May 25th, 2019.

Based on such considerations, on the flow data and on the general conditions of the riverbed <u>the water body could be classified in high state</u>.

Hydromorphological elements

The riverbed preserve semi-natural conditions for a short stretch. For most part of its length the riverbed appears to be restricted to allow the creation of ponds and reservoir. The natural flow is altered by the flow regulation operated by the Zinvhali reservoir. <u>The water body could be classified in poor state</u>.

Sinthesis: classification of the water body

The classification of the three quality elements ranges between the good state of the physico-chemical elements and of the benthic invertebrate elements, and the poor state of the hydromorphological elements. **<u>The Chinti water body could be classified in poor state</u>**.

Characteristics of the vegetation

According to the results of the monitoring, sprouting phase of the herbaceous vegetation starts earlier in in the last decade of March on the Chinti site. The most active phase of blooming starts in the middle of June and lasts to the end of July. The second part of July is the period when the floristic diversity reaches its maximum. The phase of senescence and the beginning of dormancy starts in middle of November. Seasonal variability of the floristic diversity is low as the overall increase (and decrease) of the species richness of the plants on the monitoring plots is 5% of the total richness of the plots. Annual variability of the floristic diversity is extremely low as it remined unchanged on the monitoring site during the period of the monitoring.

Rural habitat type covers quite large area of the site of Chinti and forms 60% of the floodplain vegetation. Accordingly, the floristic elements of the natural riparian habitats cover 40% of the site area.

Dominant species of the vegetation of the Tsikhisdziri monitoring site are:

Trees, shrubs, semi shrubs and lianas*: Ailanthus altissima, Alnus glutinosa, Berberis vulgaris, Carpinus orientalis, Clematis vitalba, Cornus mas, Crataegus pentagyna, Hedera helix, Morus nigra,Paliurus spina-christi, Periploca graeca, Populus × canescens, Prunus spinosa, Quercus robur subsp. Pedunculiflora (syn. Q. longipes), Rosa canina, Rubus caesius, Salix alba,*

Grasses and sedges: Anthoxanthum odoratum, Calamagrostis arundinacea, Dactylis glomerate, Calamagrostis arundinacea, Poa pratensis, Setaria pumila, Phleum pretense, Carex atherodes, C. atrata, C. rostrata, Cyperus fuscus, Eleocharis palustris,;

Legumes: *Medicago glutinosa, Trifolium ambiguum, Trifolium alpestre, Trifolium medium, Vicia sepium;*
Herbs*: Alyssum alyssoides, Ambrosia artemisiifolia, Ballota nigra, Bistorta carnea, Centaurium pulchellum, Cirsium arvense, Crupina vulgaris, Cyclamen vernum, Datisca cannabina, Epilobium hirsutum, Equisetum arvense, Erigeron annuus, Lapsana communis, Lythrum salicaria, Melandrium album, Plantago major, Prunella vulgaris, Ranunculus oreophilus, Rorippa sylvestris, Rumex acetosella, Salvia glutinosa, Senecio grandidentatus, Smilax excelsa, Solanum nigrum, Sparganium erectum, Typha latifolia, Veronica persica, Xanthium strumarium.*

The third benchmark site (Benchmark site №3) for the comparison of the vegetation diversity and structure of the sites located on the downstream areas of the Aragvi river was selected in surroundings of the v. Misaktsieli. Forest habitats which form the habitat of riparian floodplain and gallery woodlands is well developed on this locality. General difference between this site and the monitoring sites of Tsitsamuri, Chinti and Tsikhisdziri are in coverage of the woody species which is significantly (approximately 50% in overall) higher on the benchmark №3 site. This site is good example that the riparian forests can cover larger areas along the Aragvi river basin in case of better protection of the riparian habitats from anthropogenic impact. Such impact is mitigated on this locality due to ownership of this area by the company Energopro Georgia which manages the reservoir of the freshwater existed in this locality. Floristic diversity of this site is described in details in the Annex 1, B.

4.6 Tsitsamuri: confluence into the Kura River

In ist final stretch the riverbed is monocursal and runs in a small floodplain between steep ancient terraces more than 30 metres high.

Physico-chemical elements

Although the monitoring station is located downstream Zhinvali water reservoir, the water quality doesn't appear significantly changed compared to the monitoring stations located upstream the dam. All the oxygen related parameters are very good (according to them the water quality could be considered high). NH_4 concentration, is still anomalously high, but this recurring anomaly suggest a possible measurement error. The nutrients concentrations are slightly higher than upstream the dam but still compatible with good water quality. In this water body the water quality could be classified in good state.

Physico-chemical elements			
	Average	min	max
Dissolved Oxygen, mg/L	10.04	8.40	12.40
BOD5 (mg/L)	1.47	0.76	2.53
COD (mg/L)	3.26	2.10	5.18
NH_4 (mg/L)	0.31	0.21	0.37
NO_3 (mg/L)	0.59	0.17	2.31
Phosphate (PO_4-), mg/L	0.15	0.09	0.21

Benthic invertebrates

For the sampling site Tsitsamuri on the river Aragvi, samples were taken 3 times on autumn, spring and summer seasons. Macroinvertebrates mentioned below appeared into biological analyses: *Apatania sp., Ancylus sp., Baetis sp., Caenis sp., Chironomidae Gen. sp., Chrysops sp., Dicranota sp., Ephemera sp., Gomphidae Gen. sp., Hydropsyche sp., Hydroptila sp., Limnodrilus sp., Lymnaeidae Gen. sp., Rhithrogena sp., Rhyacophila sp., Simuliidae Gen. sp., Simulium sp.;* Based on this information ecological status were calculated for each sampling site. Generally, as an average result (0.55) moderate ESCS received.

Generally, the river Aragvi Tsitsamuri type has been identified as a regulated river between mountains with a bad or poor ecological status.

Considering the fact that four samples were taken on fall, spring and summer seasons, one out of four has a high ecological status, third – good and two of them moderate.

Based on such considerations, on the flow data and on the general conditions of the riverbed the water body could be classified in moderate state.

Hydromorphological elements

This river section appears to be severely affected by the lack of sediment due to the sediment trapping operated by the upstream reservoir: the riverbed is therefore deeply engraved and change its shape from a braided/wandering riverbed to a confined type. The flow is also altered by the Zinvhali reservoir. The water body could be classified in poor state.

Sinthesis: classification of the water body

The classification of the three quality elements ranges between the good state of the physic-chemical elements and of the benthic invertebrate elements, and the poor state of the hydromorphological elements. **The Tsitsamuri water body could be classified in poor state**.

Characteristics of the vegetation

According to the results of the monitoring, sprouting phase of the herbaceous vegetation starts in in the last decade of March on the Tsitsamuri site. The most active phase of blooming starts in the middle of June and lasts to the end of July. The second part of July is the period when the floristic diversity reaches its maximum. The phase of senescence and the beginning of dormancy starts in middle of November. Seasonal variability of the floristic diversity is low as the overall increase (and decrease) of the species richness of the plants on the monitoring plots is 14% of the total richness of the plots. Annual variability of the floristic diversity is extremely low as it remined unchanged on the monitoring site during the period of the monitoring. Rural habitat type covers smaller area of the site of Chinti than on the other monitoring sites of the Kura II project and forms only 30% of the floodplain vegetation. Accordingly, the floristic elements of the natural riparian habitats cover 70% of the site area.

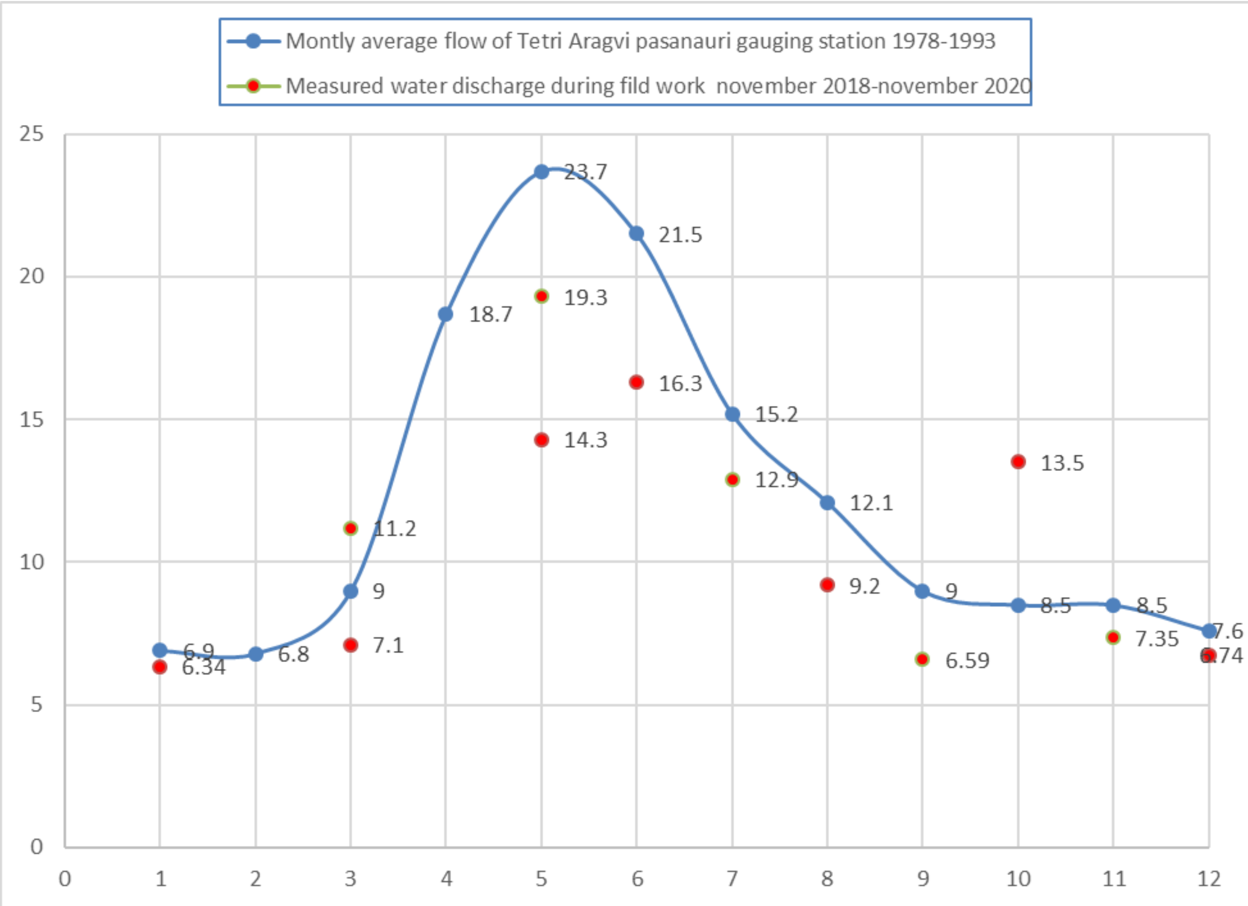
Dominant species of the vegetation of the Tsikhisdziri monitoring site are:
Trees, shrubs, semi shrubs and lianas: *Acer campestre, Ailanthus altissima, Alnus glutinosa, Berberis vulgaris, Carpinus orientalis, Cornus mas, Cornus sanguinea subsp. australis (syn. Swida australis), Crataegus pentagyna, Crataegus rhipidophylla (syn. C. kyrtostyla), Elaeagnus angustifolia, Fraxinus excelsior, Hedera helix, Lonicera orientalis, Malus domestica, Paliurus spina-christi, Periploca graeca, Populus × canescens, Prunus cerasifera, Prunus incana, Prunus spinosa, Pyrus caucasica, Rhamnus palasii, Rosa canina, Rubus caesius, Salix alba, Sambucus ebulus, Ulmus glabra;*
Grasses and sedges: *Anthoxanthum odoratum,* Calamagrostis arundinacea*, Dactylis glomerate, Calamagrostis arundinacea, Poa pratensis, Setaria pumila, Phleum pretense, Carex atherodes, C. atrata, C. rostrata, Cyperus fuscus, Eleocharis palustris;*
Legumes: *Medicago glutinosa, Trifolium medium;*
Herbs: *Dactylis glomerate, Deschampsia cespitosa, Epilobium hirsutum, Equisetum arvense, Eryngium planum, Euphorbia procera, Genista tinctorial, Gentianella caucasea, Geranium robertianum, Gymnadenia conopsea, Helleborus caucasicus, Hesperis matronalis, Humulus lupulus, Lamium album, Lapsana communis, Lysimachia verticillaris, Lythrum salicaria, Medicago lupulina, Melandrium album, Mentha longifolia, Persicaria hydropiper, Phleum pretense, Plantago major, Prunella vulgaris, Pycreus flavescens , Ranunculus oreophilus, Rubia tinctorum, Salvia verticillate, Setaria pumila, Stellaria media, Typha latifolia, Urtica dioica, Verbascum thapsus, Veronica persica, Xanthium strumarium*.
The sites of the lower stream of the Aragvi river are significantly richer in species of the woody plants than the monitoring sites located in the areas of the of the upper stream of the river. The other differences featured to the sites of the lower stream is higher abundance in invasive and rural vegetation and lower diversity of the endemic plants (see in Annex 1, A). Results of the vegetation monitoring is attached to this report as a separate file (excel database, Annex 1, C)

5. Ecological Flow Assessment for each water body

5.1 Mtiuleti (White Aragvi) 200m below dam

5.1.1 Setting of EF objectives

The annual flow regime, according to the hydrological analysis, shows High flow periods from April to August, see graph herebelow.



According to the analysis done by the expert group no social factor (e.g. important sport fishing activity) could be affected by possible flow alteration.

Presently the water flow is not altered by any withdrawing activity. The determination of the EF will not affect any existing withdrawing activity but will provide guidance for possible future water flow diversion projects.

Based on the above consideration the objectives of the EF could be the following:

- To guarantee a significant flow during the summer months, to preserve the ecological conditions for benthic and plant community to increase their species richness and to develop important biomass;

- To guarantee a significant flow during the spawning season of the brown trout;
- To keep high flow peaks to allow flooding of the floodplain, sediment flushing and the natural river channel morphological activity.

5.1.2 Determination of the survival flow

According to the analysis done by the expert group on the historical series of hydrological data the multiannual lowest minimum flow registered at this river section is 3.00 m^3/s. According to the US Aid methodology the survival flow should "exceed the value for the natural lowest daily minimum flow over the historical period of record". Thus the survival flow could be fixed at 3,2 m^3/s.

5.1.3 Determination of ecologically and socially relevant low flow periods

Ecologically relevant low flow periods are

- the summer months (from 15 of June to 15 of August) to preserve the ecological conditions for benthic and plant community to develop in number of taxa and biomass;
- the spawning season of the brown trout (from November 1 to December 31).

During he summer months, considering that the average monthly flow ranges roughly between 24 and 12 m^3/s a reasonable flow to guarantee the presence of wet habitat could be estimated at 9.20 m^3/s, that means that if the natural flow goes below this threshold no flow could be diverted during these months.

During November and December months, when the average monthly flow ranges between 8.50 and 7.60 a minimum flow to guarantee the presence of spawning habitat for the brown trout could be estimated at 4.50 m^3/s.

5.1.4 Determination of ecologically and socially relevant high flow periods

According to the hydrological analysis most of the high flow events occur yearly from April to August.   that events high flow events higher than 60 m3/s may last for several days (the highest flow registered is 173 m3/s while the minimum high flow is 24.8 m3/s).

From April to August, to allow sediment flushing, river channel morphological activity and flooding of the floodplain (to maintain the natural relationship of the river with its floodplain and allow the colonization of the floodplain by the riparian plant community), high flow events to be guaranteed could be determined as follows:

- 1 event with flow exceeding 60 m3/s with a duration of at least 5 days
- 2 events with flow exceeding 100 m3/s with a duration of at least 1 day

5.1.5 Completion of the EF requirement schedule

Survival flow				
Period	**Effective dates**	**Discharge (m^3s^{-1})**	**Percentile (Qt) from Annual FDC***	**Notes**

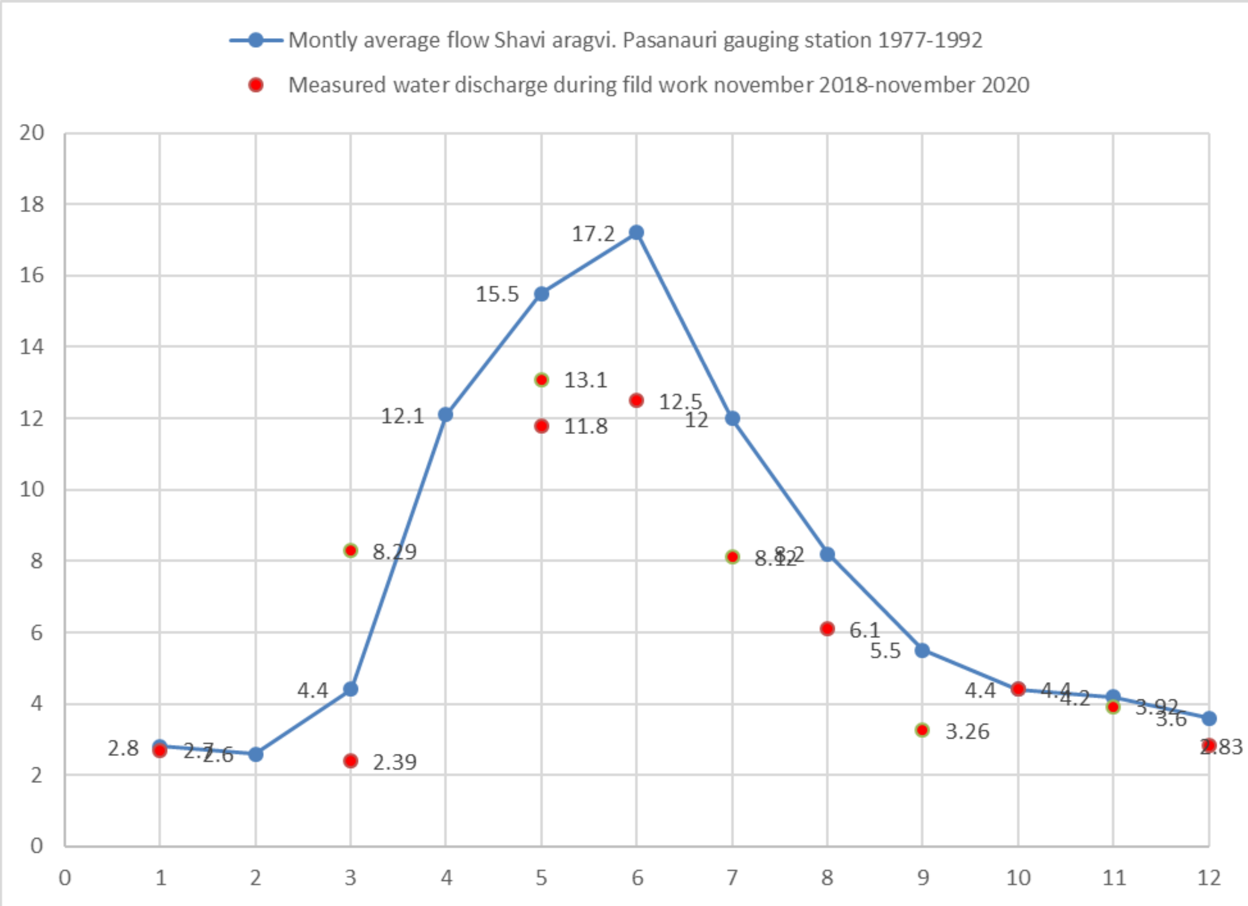
Annual	Jan - Dec	3,20		
Low flow periods				
Criterion	**Effective dates**	**Discharge (m^3s^{-1})**	**Percentile (Qt) from Annual FDC**	**Notes**
Habitat maintenance for benthic fauna and plant community	Jun 15 – Aug 15	9.20		
Spawning season of brown trout (*Salmo trutta fario*)	Nov 1 – Dec 31	4.50		
High flow events				
Motivation	**Timing**	**Duration**	**Magnitude**	**Other flow criteria****
Floodplain flooding, River channel maintenance	(Apr 1 – Aug 31)	5 days	> 60 m^3s^{-1}	-
		1 day	> 100 m^3s^{-1}	
		1 day	> 100 m^3s^{-1}	

** Annual FDC: annual flow duration curve derived from daily discharge data*
*** Other flow criteria may include: event frequency, rate of change in flow (e.g., ramping up or down in the case of hydropeaking), hydrograph shape, upper or lower discharge limits).*

5.2 Gudamakari (Black Aragvi)

5.2.1 Setting of EF objectives

The annual flow regime, according to the hydrological analysis, shows High flow periods from April to August, see graph herebelow.



According to the analysis done by the expert group no social factor (e.g. important sport fishing activity) could be affected by possible flow alteration.

Presently the water flow is not altered by any withdrawing activity. The determination of the EF will not affect any existing withdrawing activity but will provide guidance for possible future water flow diversion projects.

Based on the above consideration the objectives of the EF could be the following:

- To guarantee a significant flow during the summer months, to preserve the ecological conditions for benthic and plant community to increase their species richness and to develop important biomass;
- To guarantee a significant flow during the spawning season of the brown trout;
- To keep high flow peaks to allow flooding of the floodplain, sediment flushing and the natural river channel morphological activity.

5.2.2 Determination of the survival flow

According to the analysis done by the expert group on the historical series of hydrological data the multiannual lowest minimum flow registered at this river section is 0.70 m^3/s. According to the US

Aid methodology the survival flow should “exceed the value for the natural lowest daily minimum flow over the historical period of record”. Thus the survival flow could be fixed at 1.00 m^3/s.

5.2.3 Determination of ecologically and socially relevant low flow periods

Ecologically relevant low flow periods are

- the summer months (from 15 of June to 15 of August) to preserve the ecological conditions for benthic and plant community to develop in number of taxa and biomass;
- the spawning season of the brown trout (from November 1 to December 31).

During he summer months, considering that the average monthly flow ranges roughly between 17.2 and 8.20 m^3/s a reasonable flow to guarantee the presence of wet habitat could be estimated at 6.50 m^3/s, that means that if the natural flow goes below this threshold no flow could be diverted during these months.

During November and December months, when the average monthly flow ranges between 3.92 and 2.83 a minimum flow to guarantee the presence of spawning habitat for the brown trout could be estimated at 1.50 m^3/s.

5.2.4 Determination of ecologically and socially relevant high flow periods

According to the hydrological analysis most of the high flow events occur yearly from April to August. that events high flow events higher than 45.0 m3/s may last for several days (the highest flow registered is 156 m3/s while the minimum high flow is 21.6 m3/s).

From April to August, to allow sediment flushing, river channel morphological activity and flooding of the floodplain (to maintain the natural relationship of the river with its floodplain and allow the colonization of the floodplain by the riparian plant community), high flow events to be guaranteed could be determined as follows:

- 1 event with flow exceeding 45 m3/s with a duration of at least 5 days
- 2 events with flow exceeding 90 m3/s with a duration of at least 1 day

5.2.5 Completion of the EF requirement schedule

Survival flow				
Period	**Effective dates**	**Discharge (m^3s^{-1})**	**Percentile (Qt) from Annual FDC***	**Notes**
Annual	Jan - Dec	1.00		
Low flow periods				
Criterion	**Effective dates**	**Discharge (m^3s^{-1})**	**Percentile (Qt) from Annual FDC**	**Notes**
Habitat maintenance for benthic fauna	Jun 15 – Aug 15	6.50		

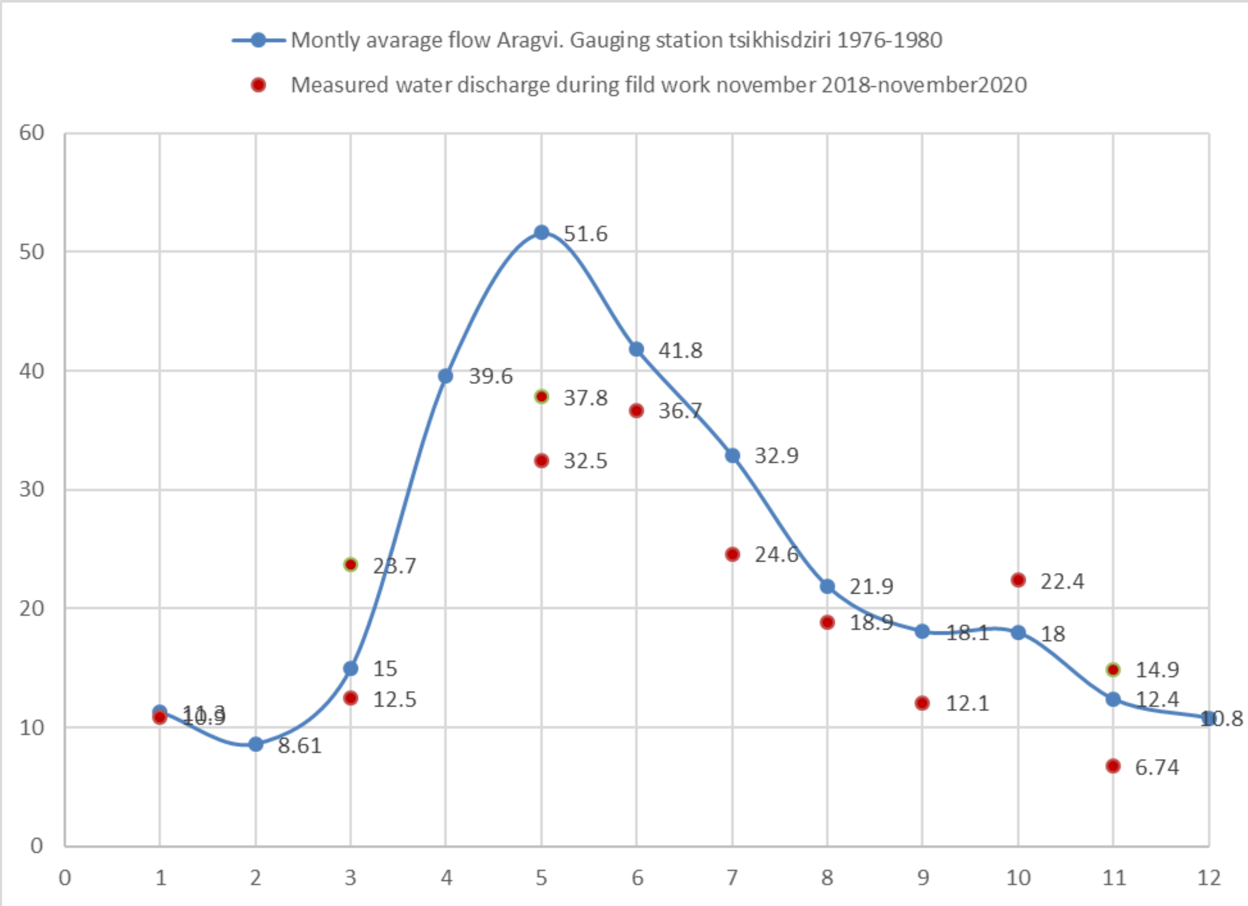
and plant community				
Spawning season of brown trout (*Salmo trutta fario*)	Nov 1 – Dec 31	1.50		
High flow events				
Motivation	**Timing**	**Duration**	**Magnitude**	**Other flow criteria****
Floodplain flooding, River channel maintenance	(Apr 1 – Aug 31)	5 days	> 45 m^3s^{-1}	-
		1 day	> 90 m^3s^{-1}	
		1 day	> 90 m^3s^{-1}	

** Annual FDC: annual flow duration curve derived from daily discharge data*
*** Other flow criteria may include: event frequency, rate of change in flow (e.g., ramping up or down in the case of hydropeaking), hydrograph shape, upper or lower discharge limits).*

5.3 Tsikhisdziri

5.3.1 Setting of EF objectives

The annual flow regime, according to the hydrological analysis, shows High flow periods from April to August, see graph herebelow.



According to the analysis done by the expert group no social factor (e.g. important sport fishing activity) could be affected by possible flow alteration.

Presently the water flow is not altered by any withdrawing activity. The determination of the EF will not affect any existing withdrawing activity but will provide guidance for possible future water flow diversion projects.

Based on the above consideration the objectives of the EF could be the following:

- To guarantee a significant flow during the summer months, to preserve the ecological conditions for benthic and plant community to increase their species richness and to develop important biomass;
- To guarantee a significant flow during the spawning season of the brown trout;
- To keep high flow peaks to allow flooding of the floodplain, sediment flushing and the natural river channel morphological activity.

5.3.2 Determination of the survival flow

According to the analysis done by the expert group on the historical series of hydrological data the multiannual lowest minimum flow registered at this river section is 3.44 m^3/s. According to the US Aid methodology the survival flow should "exceed the value for the natural lowest daily minimum flow over the historical period of record". Thus the survival flow could be fixed at 3,65 m^3/s.

5.3.3 Determination of ecologically and socially relevant low flow periods

Ecologically relevant low flow periods are

- the summer months (from 15 of June to 15 of August) to preserve the ecological conditions for benthic and plant community to develop in number of taxa and biomass;
- the spawning season of the brown trout (from November 1 to December 31).

During he summer months, considering that the average monthly flow ranges roughly between 42.0 and 22.0 m^3/s a reasonable flow to guarantee the presence of wet habitat could be estimated at 18.0 m^3/s, that means that if the natural flow goes below this threshold no flow could be diverted during these months.

During November and December months, when the average monthly flow ranges between 12.4 and 10.8 a minimum flow to guarantee the presence of spawning habitat for the brown trout could be estimated at 8.00 m^3/s.

5.3.4 Determination of ecologically and socially relevant high flow periods

According to the hydrological analysis most of the high flow events occur yearly from April to August. that events high flow events higher than 80.0 m3/s may last for several days (the highest flow registered is 340 m3/s while the minimum high flow is 70.2 m3/s).

From April to August, to allow sediment flushing, river channel morphological activity and flooding of the floodplain (to maintain the natural relationship of the river with its floodplain and allow the colonization of the floodplain by the riparian plant community), high flow events to be guaranteed could be determined as follows:

- 1 event with flow exceeding 80.0 m3/s with a duration of at least 5 days
- 2 events with flow exceeding 150 m3/s with a duration of at least 1 day

5.3.5 Completion of the EF requirement schedule

Survival flow				
Period	**Effective dates**	**Discharge (m^3s^{-1})**	**Percentile (Qt) from Annual FDC***	**Notes**
Annual	Jan - Dec	3,65		
Low flow periods				
Criterion	**Effective dates**	**Discharge (m^3s^{-1})**	**Percentile (Qt) from Annual FDC**	**Notes**
Habitat maintenance for benthic fauna and plant community	Jun 15 – Aug 15	18.0		
Spawning	Nov 1 – Dec	8.00		

season of brown trout (*Salmo trutta fario*)	31			
High flow events				
Motivation	**Timing**	**Duration**	**Magnitude**	**Other flow criteria****
Floodplain flooding, River channel maintenance	(Apr 1 – Aug 31)	5 days	> 80 m^3s^{-1}	-
		1 day	> 150 m^3s^{-1}	
		1 day	> 150 m^3s^{-1}	

** Annual FDC: annual flow duration curve derived from daily discharge data*
*** Other flow criteria may include: event frequency, rate of change in flow (e.g., ramping up or down in the case of hydropeaking), hydrograph shape, upper or lower discharge limits).*

5.4 Magaroskhari (Pshavis Aragvi)

5.4.1 Setting of EF objectives

In this section the Aragvi river appears as a mountain stream running in a narrow floodplain limited by the mountainsides. The floodplain is partially wooded and partially covered by meadows. The river bed morphology is mostly wandering but, when the valley become slightly larger there are short stretches of braided channel type. The river channel is well connected to the floodplain that is almost completely free of human settlements and infrastructure with the exception of a road that mostly run on terraces or on the mountainsides.

The ecological analysis of the water body (including the floodplain) has been done at the Magharoskari monitoring station and then replicated in a different section of the same riverbody located a few Km downstream (near the village of Tsiprani) where the impact of human activity on the floodplain is lighter and the riparian ecosystem is better preserved. In the following table the expert judgement assessment related to several ecological attributes concerning the water body and its floodplain are reported.

	Pshavis Aragvi Magharoskari (1000 m asl)	Pshavis Aragvi Tsiprani (900 m asl)
Woody species cover (%)	Poor	High
Herb cover (%)	Good	High
Taxonomical diversity of Algal flora	High	High
Taxonomical diversity of Fishes	Moderate	Moderate
Taxonomical diversity of Insect	Good	High
Taxonomical diversity Amphibians	Moderate	Moderate
Taxonomical diversity Cryptogams	High	High
Taxonomical diversity Woody species	Bad	High
Taxonomical diversity Grass species	Poor	Good

The results of the ecological analysis show a water body that is generally in good conditions, with the site of Magharoskari suffering of the more intensive use of the floodplain (lack of woody land cover and consequently of woody taxonomical diversity, intensive grazing causing loss of grass species). The aquatic ecosystem, however, appears generally in good conditions (good algal flora diversity) with a moderate taxonomical diversity of fishes and amphibians due to the natural characteristics of a mountain river with high water velocity and turbulence, where species richness of fishes and amphibians is naturally low.

The good condition of the water body is confirmed by the monitoring of the benthic community that show the presence of several taxa of macroinvertebrates typical of unaltered mountain rivers such as *Perla, Epeorus, Rhithrogena, Leuctra, Rhyacophila, Limnephilidae* etc.

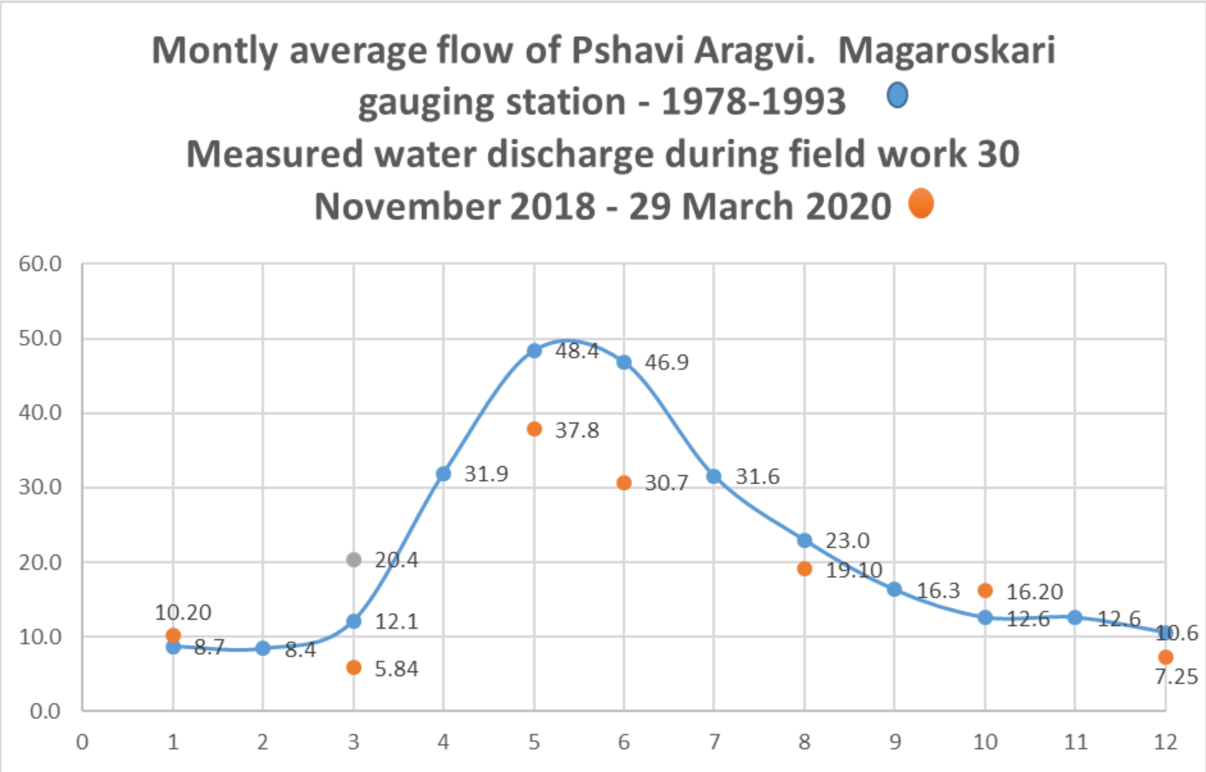
The monitoring activity doesn't included fish fauna, however, according to the literature analysis done by the ecology expert several fish species may potentially colonize the Aragvi river, see table herebelow.

Common name	**Species**
Transcaucasian bleak	*Alburnus hohenackeri*
Caucasian barbel	*Barbus ciscaucasicus*
Mursa	*Luciobarbus mursa*
Transcaucasian (white) bream	*Blicca bjoerkna transcaucasica*
Dace	*Leuciscus leuciscus*
Bulatmai barbel	*Luciobarbus capito*
Caspian Kutum	*Rutilus frisii*
Brown trout	*Salmo trutta*
Caucasian scraper	*Varicorhinus capoeta*
Kura gudgeon	*Romanogobio perseus*
Kura bleak	*Alburnus filippi*
Southern Caspian (Kura) nase	*Chondrostoma cyri*
Stone loach	*Barbatula barbatula*
Kura barbell	*Barbus lacerta*
Kura roach	*Rutilus rutilus kurensis*
Caucasian river goby	*Neogobius constructor*
Kura nase	*Chondrostoma cyri*

All the fish species listed above have no particular conservation interest (most of them are considered of "least concern" according to the IUCN red list) with the only exception of Bulatmai barbel (*Luciobarbus capito*) classified as "vulnerable". This fish, however, is typical of large, slow flow rivers and certainly could not be found in this water body of the Aragvi river. Considering the river typology and ecosystem the most sensitive fish species to flow alteration in this water body is expected to be Brown trout, *Salmo trutta fario*.

Water quality is quite good, even though the significant concentration of ammonium and phosphate show that untreated urban sewage is usually discharged into the river.

The annual flow regime, according to the hydrological analysis, shows High flow periods from April to August, see graph herebelow.



According to the analysis done by the expert group no social factor (e.g. important sport fishing activity) could be affected by possible flow alteration.

Presently the water flow is not altered by any withdrawing activity. The determination of the EF will not affect any existing withdrawing activity but will provide guidance for possible future water flow diversion projects.

Based on the above consideration the objectives of the EF could be the following:

- To guarantee a significant flow during the summer months, to preserve the ecological conditions for benthic and plant community to increase their species richness and to develop important biomass;
- To guarantee a significant flow during the spawning season of the brown trout;
- To keep high flow peaks to allow flooding of the floodplain, sediment flushing and the natural river channel morphological activity.

5.4.2 Determination of the survival flow

According to the analysis done by the expert group on the historical series of hydrological data the multiannual lowest minimum flow registered at this river section is 3.50 m^3/s. According to the US Aid methodology the survival flow should "exceed the value for the natural lowest daily minimum flow over the historical period of record". Thus the survival flow could be fixed at 3,7 m^3/s.

5.4.3 Determination of ecologically and socially relevant low flow periods

Ecologically relevant low flow periods are

- the summer months (from 15 of June to 15 of August) to preserve the ecological conditions for benthic and plant community to develop in number of taxa and biomass;
- the spawning season of the brown trout (from November 1 to December 31).

During he summer months, considering that the average monthly flow ranges roughly between 30 and 50 m^3/s a reasonable flow to guarantee the presence of wet habitat could be estimated at 15 m^3/s, that means that if the natural flow goes below this threshold no flow could be diverted during these months.

During November and December months, when the average monthly flow ranges between 10,60 and 12.60 a minimum flow to guarantee the presence of spawning habitat for the brown trout could be estimated at 8 m^3/s.

5.4.4 Determination of ecologically and socially relevant high flow periods

According to the hydrological analysis most of the high flow events occur yearly from April to August. No information has been provided by the expert group on the duration of the high flow events, but is reasonable to guess that events high flow events higher than 70 m3/s may last for several days (the highest flow registered is 338 m3/s while the minimum high flow is 50,10 m3/s).

From April to August, to allow sediment flushing, river channel morphological activity and flooding of the floodplain (to maintain the natural relationship of the river with its floodplain and allow the colonization of the floodplain by the riparian plant community), high flow events to be guaranteed could be determined as follows:

- 1 event with flow exceeding 70 m3/s with a duration of at least 5 days
- 2 events with flow exceeding 150 m3/s with a duration of at least 1 day

5.4.5 Completion of the EF requirement schedule

Survival flow				
Period	**Effective dates**	**Discharge (m^3s^{-1})**	**Percentile (Qt) from Annual FDC***	**Notes**
Annual	Jan - Dec	3,7		
Low flow periods				
Criterion	**Effective dates**	**Discharge (m^3s^{-1})**	**Percentile (Qt) from Annual**	**Notes**

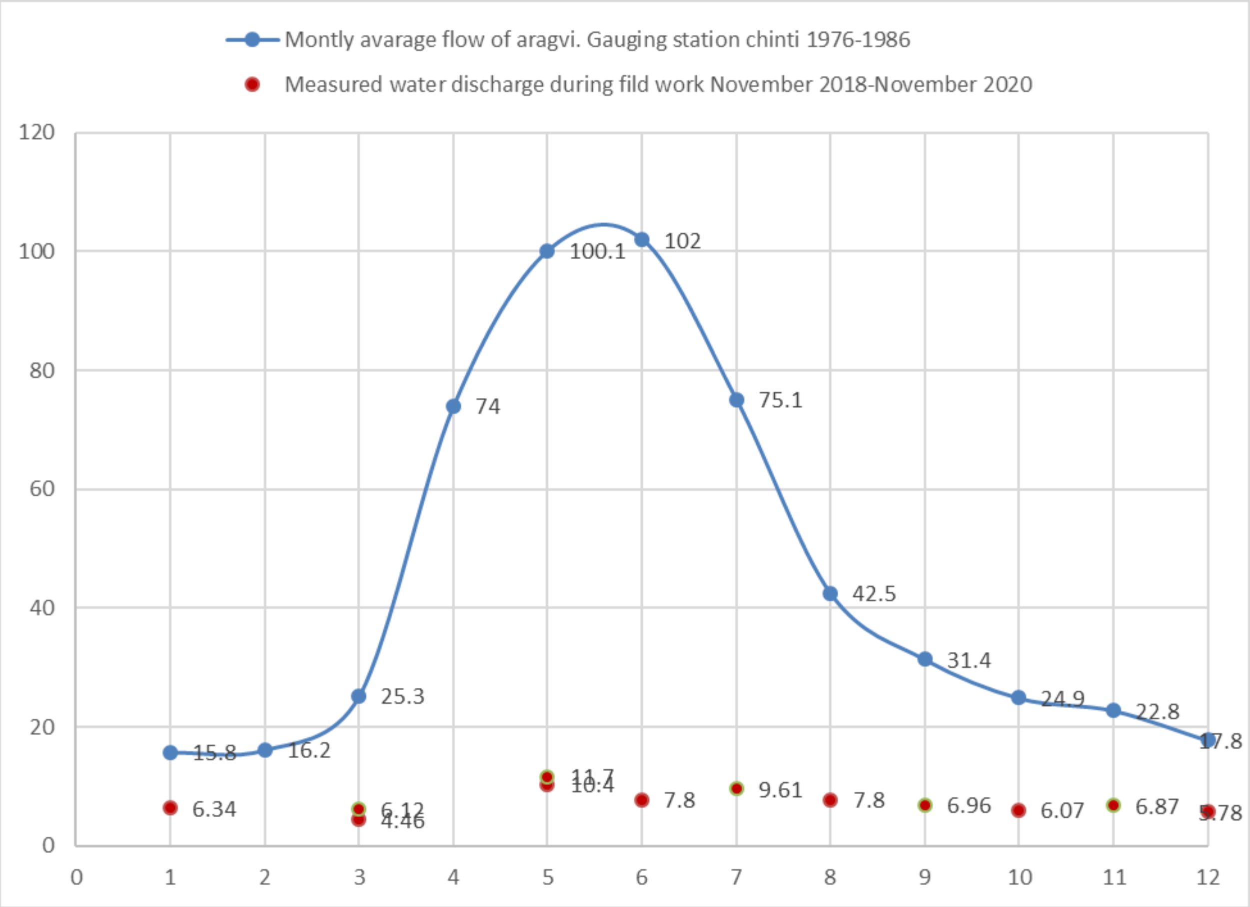
			FDC	
Habitat maintenance for benthic fauna and plant community	Jun 15 – Aug 15	15		
Spawning season of brown trout (*Salmo trutta fario*)	Nov 1 – Dec 31	8		
High flow events				
Motivation	**Timing**	**Duration**	**Magnitude**	**Other flow criteria****
Floodplain flooding, River channel maintenance	(Apr 1 – Aug 31)	5 days	> 70 m^3s^{-1}	-
		1 day	> 150 m^3s^{-1}	
		1 day	> 150 m^3s^{-1}	

** Annual FDC: annual flow duration curve derived from daily discharge data*
*** Other flow criteria may include: event frequency, rate of change in flow (e.g., ramping up or down in the case of hydropeaking), hydrograph shape, upper or lower discharge limits).*

5.5 Chinti (downstream Zhinvali water reservoir)

5.5.1 Setting of EF objectives

The annual flow regime, according to the hydrological analysis, shows High flow periods from April to August, see graph here below.



According to the analysis done by the expert group no social factor (e.g. important sport fishing activity) could be affected by possible flow alteration.

Hence that the Chinti water body is located downstream the reservoir, river is fully regulated which is also visible from the measurements. The estimation of the Eflow variables was done using old historical data (before existance of HPP).
Based on the above consideration the objectives of the EF could be the following:

- To guarantee a significant flow during the summer months, to preserve the ecological conditions for benthic and plant community to increase their species richness and to develop important biomass;
- To guarantee a significant flow during the spawning season of the brown trout;
- To keep high flow peaks to allow flooding of the floodplain, sediment flushing and the natural river channel morphological activity.

5.5.2 Determination of the survival flow

According to the analysis done by the expert group on the historical series of hydrological data the multiannual lowest minimum flow registered at this river section is 10.4 m^3/s. According to the US Aid methodology the survival flow should “exceed the value for the natural lowest daily minimum flow over the historical period of record”. Thus the survival flow could be fixed at 11.0 m^3/s.

5.5.3 Determination of ecologically and socially relevant low flow periods

Ecologically relevant low flow periods are

- the summer months (from 15 of June to 15 of August) to preserve the ecological conditions for benthic and plant community to develop in number of taxa and biomass;
- the spawning season of the brown trout (from November 1 to December 31).

During he summer months, considering that the average monthly flow ranges roughly between 102 and 42.0 m^3/s a reasonable flow to guarantee the presence of wet habitat could be estimated at 31.0 m^3/s, that means that if the natural flow goes below this threshold no flow could be diverted during these months.

During November and December months, when the average monthly flow ranges between 22.8 and 17.8 a minimum flow to guarantee the presence of spawning habitat for the brown trout could be estimated at 14.0 m^3/s.

5.5.4 Determination of ecologically and socially relevant high flow periods

According to the hydrological analysis most of the high flow events occur yearly from April to August.   that events high flow events higher than 250 m3/s may last for several days (the highest flow registered is 660 m3/s while the minimum high flow is 67.2 m3/s).

From April to August, to allow sediment flushing, river channel morphological activity and flooding of the floodplain (to maintain the natural relationship of the river with its floodplain and allow the colonization of the floodplain by the riparian plant community), high flow events to be guaranteed could be determined as follows:

- 1 event with flow exceeding 250 m3/s with a duration of at least 5 days
- 2 events with flow exceeding 300 m3/s with a duration of at least 1 day

5.5.5 Completion of the EF requirement schedule

Survival flow				
Period	**Effective dates**	**Discharge (m^3s^{-1})**	**Percentile (Qt) from Annual FDC***	**Notes**
Annual	Jan - Dec	11.0		
Low flow periods				
Criterion	**Effective dates**	**Discharge (m^3s^{-1})**	**Percentile (Qt) from Annual FDC**	**Notes**
Habitat maintenance for benthic fauna and plant community	Jun 15 – Aug 15	31.0		
Spawning season of brown trout (*Salmo trutta fario*)	Nov 1 – Dec 31	14.0		
High flow events				
Motivation	**Timing**	**Duration**	**Magnitude**	**Other flow criteria****
Floodplain flooding, River channel	(Apr 1 – Aug 31)	5 days	> 250 m^3s^{-1}	-
		1 day	> 300 m^3s^{-1}	
		1 day	> 300 m^3s^{-1}	

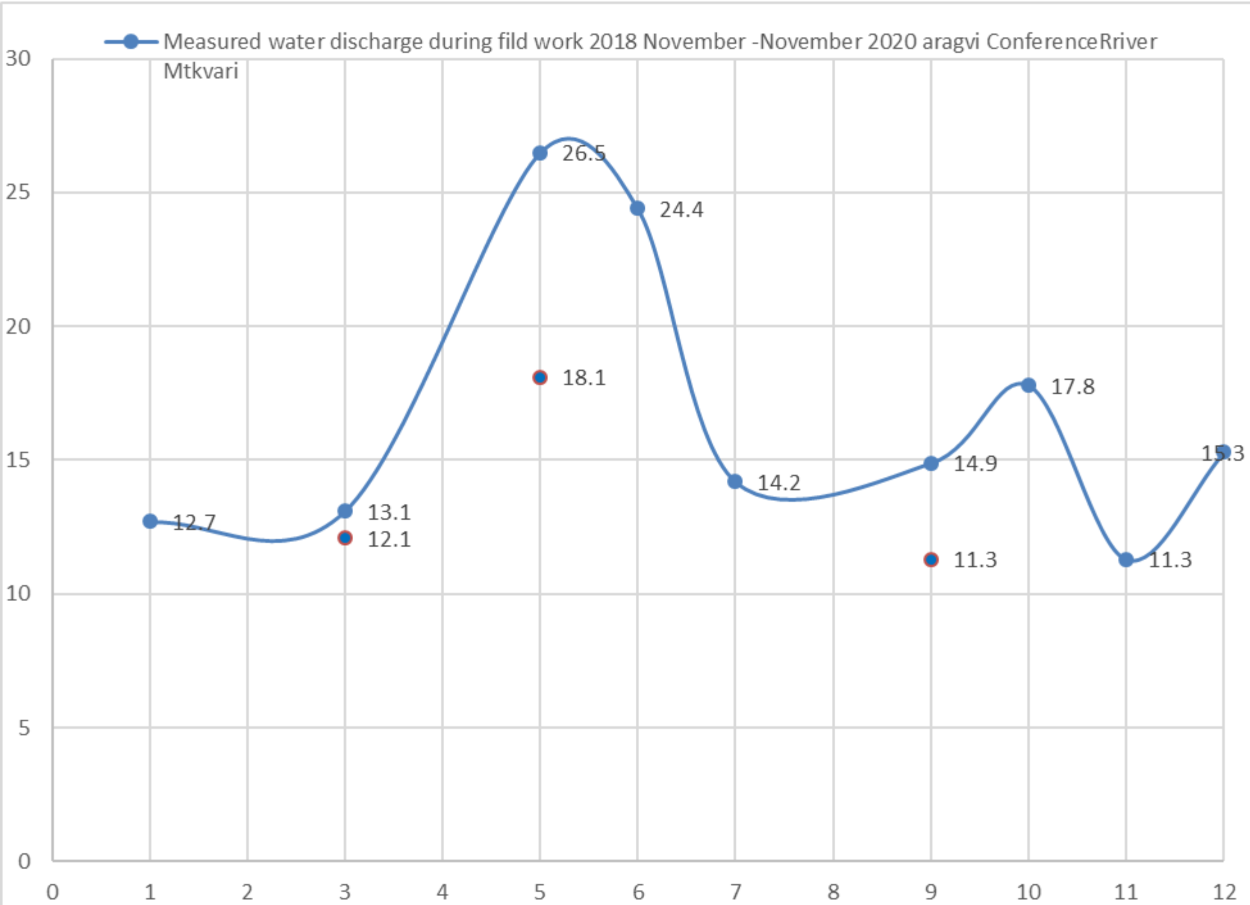
maintenance				

** Annual FDC: annual flow duration curve derived from daily discharge data*
*** Other flow criteria may include: event frequency, rate of change in flow (e.g., ramping up or down in the case of hydropeaking), hydrograph shape, upper or lower discharge limits).*

5.6 Tsitsamuri: confluence into the Kura River

5.6.1 Setting of EF objectives

The annual flow regime, according to the hydrological analysis, shows High flow periods from April to August, see graph here below.



According to the analysis done by the expert group no social factor (e.g. important sport fishing activity) could be affected by possible flow alteration.

Hence that the Chinti water body is located downstream the reservoir, river is fully regulated which is also visible from the measurements. The estimation of the Eflow variables was done using old historical data (before existance of HPP).Based on the above consideration the objectives of the EF could be the following:

- To guarantee a significant flow during the summer months, to preserve the ecological conditions for benthic and plant community to increase their species richness and to develop important biomass;
- To guarantee a significant flow during the spawning season of the brown trout;
- To keep high flow peaks to allow flooding of the floodplain, sediment flushing and the natural river channel morphological activity.

5.6.2 Determination of the survival flow

There is no historical data near the river Aragvi Mchkheta, we used the analog method, we used the analog method to find the Aragvi hydrological station Chinti, the area of Aragvi Chinti is 1900 km2, the area of the river Aragvi Mtskheta is 2740 km2, therefore the transfer coefficient is 1.44
According to the analysis done by the expert group on the historical series of hydrological data the multiannual lowest minimum flow registered at this river section is 14.9 m3/s. According to the US Aid methodology the survival flow should "exceed the value for the natural lowest daily minimum flow over the historical period of record". Thus the survival flow could be fixed at 15.8 m^3/s.

5.6.3 Determination of ecologically and socially relevant low flow periods

Ecologically relevant low flow periods are

- the summer months (from 15 of June to 15 of August) to preserve the ecological conditions for benthic and plant community to develop in number of taxa and biomass;
- the spawning season of the brown trout (from November 1 to December 31).

During he summer months, considering that the average monthly flow ranges roughly between 146 and 60.4 m^3/s a reasonable flow to guarantee the presence of wet habitat could be estimated at 31.0 m^3/s, that means that if the natural flow goes below this threshold no flow could be diverted during these months.

During November and December months, when the average monthly flow ranges between 38.8 and 25.6 a minimum flow to guarantee the presence of spawning habitat for the brown trout could be estimated at 20.1 m^3/s.

5.6.4 Determination of ecologically and socially relevant high flow periods

According to the hydrological analysis most of the high flow events occur yearly from April to August. that events high flow events higher than 360 m3/s may last for several days (the highest flow registered is 950 m3/s while the minimum high flow is 96.7 m3/s).

From April to August, to allow sediment flushing, river channel morphological activity and flooding of the floodplain (to maintain the natural relationship of the river with its floodplain and allow the colonization of the floodplain by the riparian plant community), high flow events to be guaranteed could be determined as follows:

- 1 event with flow exceeding 360 m3/s with a duration of at least 5 days
- 2 events with flow exceeding 432 m3/s with a duration of at least 1 day

5.6.5 Completion of the EF requirement schedule

Survival flow				
Period	**Effective dates**	**Discharge (m^3s^{-1})**	**Percentile (Qt) from Annual**	**Notes**

			FDC*	
Annual	Jan - Dec	15.8		
Low flow periods				
Criterion	**Effective dates**	**Discharge (m^3s^{-1})**	**Percentile (Qt) from Annual FDC**	**Notes**
Habitat maintenance for benthic fauna and plant community	Jun 15 – Aug 15	44.6		
Spawning season of brown trout (*Salmo trutta fario*)	Nov 1 – Dec 31	20.1		
High flow events				
Motivation	**Timing**	**Duration**	**Magnitude**	**Other flow criteria****
Floodplain flooding, River channel maintenance	(Apr 1 – Aug 31)	5 days	> 360 m^3s^{-1}	-
		1 day	> 432 m^3s^{-1}	
		1 day	> 432 m^3s^{-1}	

** Annual FDC: annual flow duration curve derived from daily discharge data*
*** Other flow criteria may include: event frequency, rate of change in flow (e.g., ramping up or down in the case of hydropeaking), hydrograph shape, upper or lower discharge limits). limits).*

6. Roadmap for the institutionalization of the methodology within the current water resources management system in Georgia

The European Union Water Framework Directive (WFD), that was taken as reference legislation approach by the Kura II Project water, introduces new, broader ecological objectives, designed to protect and, where necessary, restore the structure and function of aquatic ecosystems themselves, and thereby safeguard the sustainable use of water resources.

The hydrological regime is a "master variable" of aquatic ecosystems strongly correlated with many physical-chemical characteristics such as water temperature, channel geomorphology, and habitat diversity, which are critical to preserving the ecological integrity of aquatic ecosystems. For the purpose of protecting the environment is necessary to consider the water needs of aquatic ecosystems, thus contributing to preserve, protect and improve environmental quality and the rational use of water resources. The Directive is explicit in this regard since the classification of ecological status should be considered a hydrological regime consistent with environmental objectives.

The WFD does not specify the flow regime required to achieve the Good Status but requires that the flow regime should provide conditions “consistent with the achievement of the values specified for the Biological Quality Elements”. Good status is unlikely to be reached in a water body with significantly altered flows, as this will result in changes to the river ecosystem through modification of physical habitat and alterations in erosion and sediment supply rates. Consequently, restoring a suitable flow regime may well be a necessary measure in an aquatic ecosystem that fails good status.

That's why to guarantee ad Environmental Flow in each water body, allowing it to reach the good status is one of the typical measures envisaged by River Basin Management Plan throughout European Union.

The WFD doesn't regulate the water abstraction procedures, that are left to the members state regulatory practice, however every EU member state regulate water abstraction through specific licensing procedures. In Italy, water abstraction licences are now issued by the Regional Governments (while in the past the Ministry of Public Works was the issuing Authority). In spain water abstraction license are awarded, supervised and managed by River Basin Authorities, which can limit abstractions either temporarily or permanently, e.g., to meet environmental regulations.
The water abstraction license is the key administrative act to introduce the EFA procedure, because the issuing of the license could be subject to an EFA study and the water abstraction rule could be set accordingly. In several European countries, the EFA is part of the Environmental Impact Assessment procedure that is always required for water abstraction projects, with the exception of very peculiar cases of very small river water abstraction facilities.

There are several major laws and numerous sublegal acts regulating the protection and management of water resources in Georgia. However, current water-related legislation is inconsistent and does not provide clear regulation of some important topics. Currently, Georgian legislation does not define the meaning and the method of calculation of environmental flow. Approximation of the existing Georgian legislation and standards to the EU and other international standards is needed. It would be mentioned that the new Water Law is prepared in which ecological flow is defined.

The main principle of the new Law is to implement a River Basin Management approach which involves coordination of different sectors to avoid conflict between different water users. The river basin management approach also needs to consider water availability and any upstream-downstream interactions.

The development and implementation of an overall policy in water resources management is the responsibility of the Ministry of Environmental Protection and Agriculture of Georgia (MEPA). Specifically, the Ministry is in charge of developing legislation, conducting ecological expertise for environmental permitting, setting norms for water abstraction and wastewater discharge, collecting and processing statistical forms submitted annually by users of water resources (irrigation companies, hydroelectric and thermoelectric enterprises and industries), etc. LEPL National Environmental Agency (NEA) is responsible for the creation of monitoring systems that measure the quality and quantity of the surface and ground waters throughout the whole territory of Georgia. Department of Environmental Supervision (DES) of MEPA controls implementation of the conditions of the permits and technical regulations set for surface waters.

For the implementation of the proposed methodology on calculation of environmental flow very important capacity building of the NEA. The NEA in Georgia is only one state institution responsible for hydrological, meteorological and environmental pollution monitoring; timely gathering information of hydrometeorological, geological and environmental pollution observation on the territory of Georgia and its dissemination on national and international levels, also for assessment of actual conditions of the existing hydrometeorological, geological and environmental quality on the territory of Georgia, preparation and dissemination of relevant informational products.

In the implementation of the proposed methodology the two departments of the NEA will be involved, namely Hydrometeorological Department and Environmental Pollution Monitoring Department. Despite the positive changes during the last years such as increasing of monitoring network, capacity building of laboratory activities the further developments are needed, especially hiring of the new relevant staff, training of personnel, more regular and permanent monitoring.

Kura-Aras project method can be proposed for calculation of the mean Ecological Flows, but further surveys are needed. The experts from the Universities can be involved for flora and fauna surveys in case of necessary funding. Also institutional strengthening of the National Environmental Agency is needed to continue the further surveys and implementation of the proposed methodology for the calculation of the environmental flow for the Aragvi River which can be implemented in the future for the other rivers as well.

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