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Effects of multiple dam projects on river ecology and climate change: Çoruh River Basin, Turkey

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Abstract. Depending on the increased energy needs, a large number of dams have been built around the world. These dams have significant impacts on river ecology and climate change. When the climate change scenarios are examined, it is stated that the annual average temperature in Turkey will increase by 2.5-4 degrees in the future years, the south of the country will be opposed to the severe drought threat, and the northern regions will have a flood risk. In particular, it can be predicted that many dams and dam lakes built in the North of Turkey may increase the impact of climate change. In this study, the effects of the dams constructed in Ç oruh basin on climate change are examined. Environmental and ecological problems of dam reservoirs have been examined. As a result of the data received from meteorological stations, it was determined that temperature and rainfall changes in the region. In this direction, solution proposal is presented.

Keywords: Coruh Valley; climate change; ecology; environmental; multiple dam

1. Introduction

Freshwater, seawater, coastal and terrestrial biodiversity have been threatened by the use of water resources by humans. The global threat is 11-25% for terrestrial vertebrates and 13-65% for fresh water groups. While the impacts of large dams on freshwater resources are emphasized, these structures should be examined for significant impacts on terrestrial biodiversity. The flow of 60% of rivers around the world is controlled. There are over 40,000 large dams. The construction of dams and reservoirs affects the biological diversity of fresh waters. International agreements and organizations have developed standards to reduce the negative impacts of people on biodiversity (Maingi 2002). The most endangered species in the ecosystem are freshwater organisms. Dams are one of the main causes of this danger. The greatest parts of the dam damages are caused by the rivers impinging on the natural flow patterns and blocking the migration routes of the water creatures. This causes objections to the dams and their operation (Berkün *et al.* 2008). Although the effects of dams on river ecology vary widely, it is possible, according to many researchers' statements (Baxter 1977, Ludwig 1982, Dudgeon 1995, Sadler 1996, Zhao *et al.* 2010, Aras 2012, Zhao *et al.* 2013, Skoulikaris and Ganoulis 2017) to collect them in two general categories, namely

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the presence of the dam-reservoir and the effect of the operation of the dam.

We can explain the impacts of the operation of the dam as a change of downstream hydrology, change of downstream water quality and change of diversity of habitats in rivers, onshore and floodplains due to the prevention of floods. Also we can explain the impacts of the presence of the dam and the reservoir as a failure of the dam's position in the valley (habitat loss), deterioration of the morphology of the downstream side due to the changing sediment load (erosion), change in water quality on the downstream side (river temperature, nutrient load, turbidity, dissolved gas quantity, heavy metal and mineral concentrations) and blocking of organism movements and reduction of biological diversity (Toprak *et al.* 2013). On the other hand, socio-economic and cultural influences also have positive and negative effects from the construction phase of the dam. In the construction phase, the value of the land varies depending on the nature and size of the underwater land. The local economy is reviving due to the work force at the construction stage. This revival has a positive effect on infrastructure services and social services (school, health facility, etc). The dam lake is also a resource for recreation and aquaculture production. However, the loss of cultural values can be a problem because the natural and historical assets on the site are not protected.

After the construction of the dams, the flow conditions at the downstream part vary depending on the operating conditions and the peak values are lost. The changes in the amount of flow in the natural environment are a display for the creatures in the ecosystem (for example: determining migration times). These natural flow values, which are important for the life of the water, lose their ecological value after the dam construction and the structure of the creatures is deteriorating (Barrow 1981, Alam *et al.* 1995, Canter 1999, Zeng *et al.* 1998).

It is known that large water bodies are influential on environmental climate. This effect can be expected to manifest itself as a moist and temperate structure in terrestrial climate zones. Hydroelectric power plants and dams have climatic, hydrological, ecological, socio-economic and cultural effects. The water collecting part of a hydropower generating plant (dam reservoir) creates environmental impact. Climatic effects occur because of the larger surface area of the dam lake and the evaporation. In this way, the humidity of the air increases and the temperature, precipitation, and wind phenomena vary. In this case, natural vegetation, agricultural plants and aquatic terrestrial animals on the site are suddenly changing and adaptable species are continuing their lives (Williams and Veltrop 1991, Zhao *et al.* 2006).

The most important parameter of the effect of dams on climate change is greenhouse gas production, even if it is within certain limits. Dams cause climate change and therefore global warming because they have the danger of methane gas release. There is a risk that the dam lake will release methane gas instead of atmospheric carbon dioxide. Because the plants in the reservoir are rotting and the amount of dissolved oxygen in the reservoir comes to very low levels. The effect of methane gas released to the atmosphere on global warming is greater than that of carbon dioxide (ICOLD 1997).

2. Çoruh River basin development project

2.1 Characteristics of Çoruh Basin

The Çoruh basin contains some parts of Bayburt, Erzurum and Artvin in north-east of Turkey. The Çoruh river, which gives the name to the basin, originates from the Mescit mountains within

Table 1 Streams and creeks flowing into Coruh River

Streams/Creek	Drainage area (km^2)	Streams/Creek	Drainage area (km^2)
Pulur Creek	20	Hatila Creek	223.6
Oltu Creek	687.7	Altıparmak Creek	860
Tortum Creek	2000	Gungormez Stream	65
Berta Creek	5848	Cala Stream	93.2
Çavuslar Stream	62.3	Çamlıkaya Stream	124
Aralık Stream	72	Aksu Stream	224
Deriskel Stream	178	Baskoy Stream	63
Cihala Stream	11.7	Capan Stream	153
Murgul Stream	360.6	Anuri Stream	113
Karatas Stream	116	Karakoc Stream	90

the boundaries of Erzurum province. After passing through the border of Erzurum province, the Coruh river passes to Artvin province and leaves the country boundaries at a height of approximately 50 m. It is poured from the borders of Georgia to the Black Sea. The Coruh River main arm length is about 296 km. The Coruh basin has an area of about 20,000 km^2 and the average amount of rainfall per m^2 in the basin is about 480 mm and the basin water potential is about 6.50 billion m^3. The basin is characterized by the climatic characteristics of the classical continental climate in Bayburt, while the Mediterranean climate features are observed in the regions where the altitude is lower in the downstream parts of the river. There are many mountains on the level of 2500-3000-3500 m in the basin. Some of those mountains are Kaçkar Mountain (3932 m) and Altıparmak Mountain (3562 m). The area under the 500 m of the basin is about 400 km^2. Because of this feature, Çoruh river is the fastest flowing river of Turkey (Aydogan *et al.* 2016). The important creek and streams that drain their waters into the Coruh River are given in Table 1.

The Coruh River is considered as one of the most suitable basins for both dam and river type power plants due to its high shortfall in short distance. Because of the characteristic feature of the Coruh basin, the continental climate is the transition from the temperate climate as the coastal region progresses to the inner regions. The city of Artvin has a moist climax. The winters are cool, the summers warm. The city of Erzurum has semi-arid-less moist climates. The winters are cold and the summers are warm. Bayburt has a dewy muddy city. The winters are cold and the summers are warm. The drought is increasing as you go to the inner zone. The average annual precipitation in Hopa-Kemalpaşa along the Black Sea coast is 2754 mm. The average precipitation is 1250 mm in Borçka, 689 mm in Artvin Province, 446 mm in Ardanuç, 295 mm in Yusufeli, 440 mm in İspir It is 353 mm in Oltu. If we look at the average rainfall for many years; It is 716.8 mm in Artvin, 405.3 mm in Erzurum and 442.8 mm in Bayburt. The annual precipitation in Artvin is above the Turkey average of 643 mm.

Çoruh Basin is located in the Colchic Region of the Euro-Siberian Flora Region. When the local characteristics are taken into consideration, Mediterranean-based taxa are frequently encountered between 200-400 meters elevations along the Çoruh Valley. The forest formations in the region are spreading as very moist temperate broadleaved forests (alder forests, chestnut forests and beech forests), moist-cold coniferous forests, dry forests and bush formations. In addition, there are several fish species in the Coruh River, mainly carp and mullet.

There is significant precipitation in the province of Artvin. Even in arid months, the amount of rainfall is quite high. According to Köppen-Geiger, the climate is Cfb. The annual average temperature of Artvin is 11.8. The average annual precipitation is 1168 mm. The average values for the city are given in Table 2 (MGM 2017). The Coruh basin land use is given in Table 3.

2.2 Ecological importance of Coruh River Basin

Çoruh Valley is a region with ecologically significant features both nationally and internationally. One of the 122 important plant areas determined in Turkey within the scope of "Turkey's Important Plant Areas Study" is "Çoruh Valley Important Plant Area" (IPA). A large part of this area is located within Artvi" borders. The Coruh Valley IPA covers 162,834 hectares, including the central and lower sections of the Coruh River.

The mountains around the river rise up to 3000 m within 15 km, while the valley floor drops from 450 m to 75 m on the border of Georgia. The fact that the climate is so soft has allowed the Mediterranean vegetation elements to develop in the basin. There are forests, small scattered peanut pine (Pinus pinea) and pseudomorphs in the lower parts of the basin while there are large dry steeps on the slopes of the valley. The Coruh Valley has an extraordinary and rich fluoride. Some families are represented at very high rates in the IPA flor with about 750 taxa. It is known that about 104 of these taxa are rarely found throughout the country. The fact that the area contains so many rare taxa around the country is rare in a single river valley (WWF 2017).

Table 2 Average values in Artvin Province (1926-2016)

ARTVİN	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
Average temperature (˚C)	2.8	3.9	7.1	11.9	15.9	18.8	20.8	21.0	18.1	14.0	9.1	4.5	12.3
Average highest (˚C) temperature	6.2	8.2	12.3	17.8	21.9	24.2	25.7	26.3	23.8	19.5	13.3	7.7	17.2
Average lowest temperature (˚C)	-0.3	0.3	2.8	7.1	11.2	14.2	16.8	17.1	14.1	10.2	5.6	1.6	8.4
Average sunrise time (hours)	2.2	3.2	4.2	5.2	6.3	7.1	6.5	6.6	6.3	4.4	3.1	2.1	57.2
Average number of rainy days	12.8	12.7	13.2	12.8	13.9	12.7	8.2	8.1	8.5	10.9	10.8	11.7	136.3
Monthly total rainfall averages (kg/m^2)	85.8	72.3	60.8	54.2	52.2	50.0	30.9	29.6	37.5	61.4	77.0	88.5	700.2
Between 1926 and 2016													
The highest temperature	18.9	21.5	28.4	34.4	36.4	39.0	42.0	43.0	39.5	33.9	27.9	20.9	43.0
The lowest temperature	-16.1	-11.9	-9.8	-7.1	-0.6	3.7	9.5	9.5	4.2	-1.6	-8.2	-10.8	-16.1

Table 3 Land use of Çoruh Basin (Toker 2010)

Land Use	Land (Hec)	Land (%)
Forest and Semi-Natural Areas	1650427	81.52
Agricultural Areas	361978	17.88
Construction Areas	6750	0.33
Surface Areas	4452	0.22
Wetlands	1047	0.05
TOTAL	2024654	100

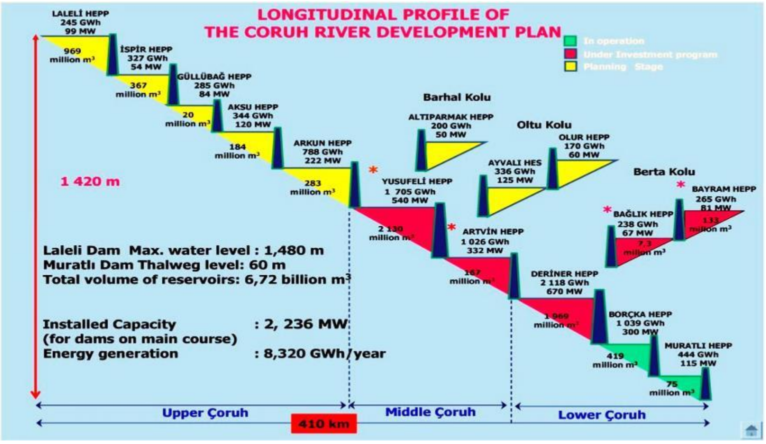


Fig. 1 Longitudinal profile of the Coruh River development plan

It is estimated that the Coruh Valley has been covered with forest cover largely from the past. The pseudomakers (a kind of plant cover, a similar damp bush) are quite common along the valley (300-850 m) stretching between Yusufeli and Borçka. The characteristics of the Coruh Valley are further enriched with various wetland vegetation coverings.

As mentioned above, there are a large number of species at risk both globally and nationally, with large dams, mining activities, road constructions and illegal or excessive collection initiated in the Coruh Valley, which has a very rich plant variety.

2.3 Multiple dam project

The work of General Directorate of Electrical Power Resources Survey and Development Administration (EIE) in Çoruh Basin started with current measurements in 1938. Studies started in 1954 in the main and side branches of the Coruh River continued until the year 2007. The General Directorate has carried out a total of 46 hydroelectric power plant projects, including 16 dams and 30 regulators in Coruh River and its sidewalks. The total installed capacity of 16 projects developed on the Coruh River and its side arms is 3105 MW and the hydroelectric potential is 9 billion 614 million kWh (Toker 2010).

Hydroelectric potential of four dams built in lower and middle Coruh Basin (Muratlı, Borçka, Deriner, Yusufeli Dams) is 1625 MW. And their installed capacity is 5 billion 428 million kWh per year. A total of 162 river type HEPPs were planned in the Çoruh Basin after the “Private

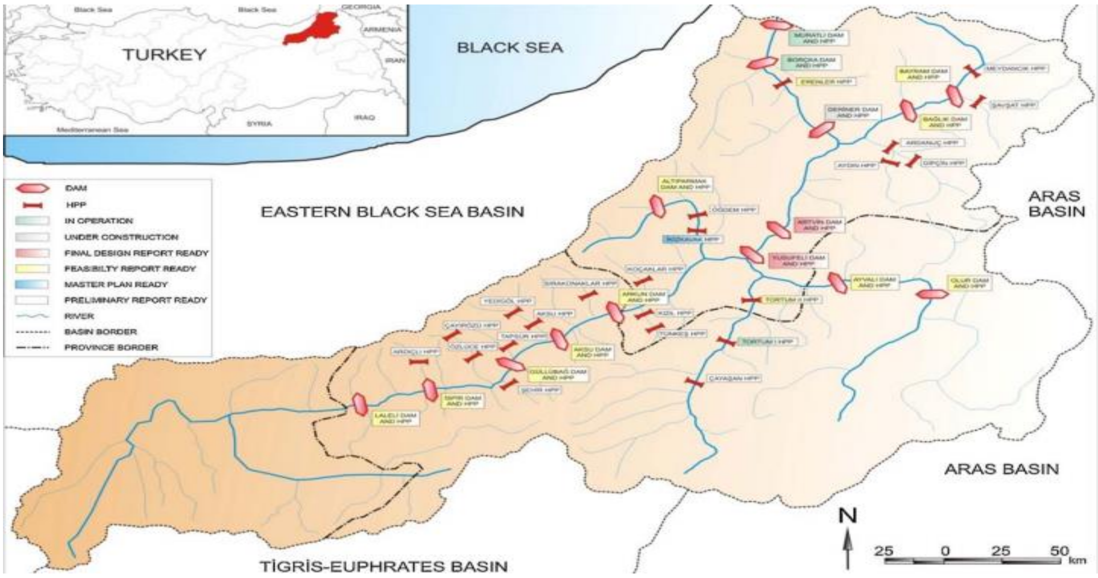


Fig. 2 Dams and HEPP projects on the Coruh Basin development plan (Akpınar *et al.* 2011)

Sector Water Usage Agreements" opened with Turkish Law No: 4628. The total installed capacity of these projects is 2875 MW and the annual energy production is 8 billion 626 million kWh. Thus, the total energy potential of the basin is 16 billion kilowatt hours per year, when all projects (operating, built and planned) are considered. All the projects in Çoruh basin are given in Fig. 1. The aim of many dam constructions on the Coruh River is to meet the electricity needs of the country from renewable energy sources.

Muratlı, Borçka, Artvin and Deriner dams on the main arm and Arkun, Güllübağ and Ayvalı dams on the side branches have been completed and they are in operation. The Yusufeli dam is under construction. In the middle of 2017, it is considered to start building the dam body (Fig. 2). Other dams are in the planning stage. Muratlı Dam has a storage capacity of 75 million m^3, Borcka Dam has a storage capacity of 419 million m^3 and Artvin Dam has a storage capacity of 167 million m^3. The storage capacity of the Deriner dam, which is one of the biggest dams in Turkey and the world, is 1969 million m^3.

Muratlı Dam is located at a distance of 17 km from the town of Borçka in the province of Artvin, 2 km from the town of Muratlı and 100 m from the border of Georgia. The dam was started to be built in September 1999. On 2 June 2005, the dam started to produce electricity with two turbines, each with a capacity of 57.5 MWe. The dam type is filled with rock body and the lake area from the normal water level of the dam is 4.10 km^2. The annual average flow is 6060 million m^3 and the precipitation area is 19748 km^2.

Borcka Dam is a clay-based, rock-filled dam built on an alluvium, 2.5 km south-southwest of Borçka town center and 25 km north-west of Artvin province. Borçka Dam and HEPP facility construction works started on 01.09.1999 day. As of 08.04.2007, the energy production started at the dam, and at the end of February 2008, a total of 634948 MWh of power was produced, 570804 MWh for the first district and 64144 MWh for the second district. The precipitation area of the dam is 19255 km^2 and the annual average flow is 5.66 billion m^3.

Artvin Dam is 30 km downstream of Artvin Yusufeli District and 20 km downstream of Oltu

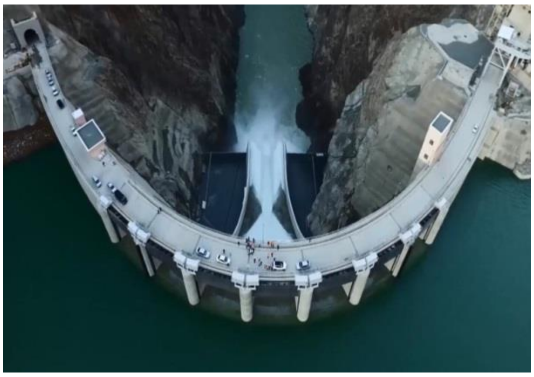
Stream. The average annual flow is 3837 million m^3 and the precipitation area is 15540 km^2. The height of the dam, which is the arch type dam, is 180 meters. The installed power will be 332,00 MW and the total energy will be 1026,00 GWh per year with 116,20 meter height. The first unit was launched on December 10, 2015, the second unit was launched on February 3, 2016 with a capacity of 11609 MW and electricity production started.

The Deriner Dam and Hydroelectric Power Plant are located on the Coruh River in the Eastern Black Sea Region of Turkey and in the Artvin City Center. Deriner Dam is the third dam from the downstream in Çoruh project.

Deriner Dam, which is the first key dam on the Coruh River, is Turkey's largest dam among the Double Curvature Concrete Arch Dams and the third largest dam in the world. The Deriner Dam is planned to have a height of 249 m, a length of 720 m and a width of 18 meters in crest. The average annual flow is 4.84 billion m^3 and the regulation rate is 94%. It has the second largest reservoir with a storage volume of 1.97 billion m3 on the Coruh Basin. With this feature, it will also undertake the task of regulating reservoirs of downstream dams (DSI 2017) (Fig. 3). After the dam was opened on December 12, 2012, the first turbine began producing electricity on July 5, 2013, the second and third turbines on August 2, 2013, and the fourth and last turbine on October 2, 2013.

(a) Muratlı Dam

(b)Borçka Dam



(c) Artvin Dam

(d) Deriner Dam

Fig. 3 Four large dams (in operation) on the Coruh Basin Project

3. Impacts of the project on the basin

3.1 The situation in Turkey

The importance of climate in human life is how climate affects social and economic life. Many national and international organizations, central and local governments and non-governmental organizations are striving to identify the changes that can occur in the climate. The most important of these efforts is the modelling work. With the development of technology, the variables that express the environmental conditions can be found in the models in more detail. Climate models have been used since 1970s with the use of computers for scientific purposes. In the first models, only the atmospheric parameters were studied. Later, parallel to the developments, factors such as land surface, oceans, sea ice, sulphate, aerosols, carbon cycle, dynamic vegetation and chemistry of the atmosphere are the input parameters to the models (Ö nol and Semazzi 2009, Demircan *et al.* 2014, Demircan *et al.* 2017). The influence of the electricity consumption of the climate is also investigated (Ang *et al.* 2017).

Climate is the average weather condition experienced in large time spans and larger areas. Climate normal are averages of consecutive thirty years calculated from climate data. Using climate norms is a crucial tool for building global assessment and climate monitoring work. Scientists, international institutions and organizations use climate reference periods of 1961-1990, 1971-2000 and 1981-2010 in national and regional based climate monitoring, climate trend, climate change and climate model studies (Özdoğan 2011).

In the context of climate change, it is predicted that there will be serious risks in the river basins of Turkey in new climatic conditions (Özdoğan 2011). One of these is the decrease in the amount of rainfall especially in the inner parts of Anatolia and the basins in the south, especially the Euphrates-Dicle basin. The second is that the increasing temperatures cause changes in the rainfall type and the winter rainfall turns into rain (Sen *et al.* 2011). Snow is an important source of water throughout the year. Also, increased temperatures will cause premature ejaculation in the snow. The third problem is the risk of excessive rainfall in the western and northern coastal areas of Anatolia, especially in summer. These extreme rainfalls can cause floods. Also increased temperatures; it could lead to an increase in the number and severity of extreme weather events such as storms, hail, and hoses (Fujihara *et al.* 2008, Evans 2009, Hemming *et al.* 2010, Bozkurt *et al.* 2015).

Turkey is located in a large climatic region in the western part of the subtropical belt valley called Mediterranean climate. In Turkey, which is surrounded by sea on three sides and has an average altitude of about 1100 m, many subclimate types have developed. This diversity of climate types is related to the fact that Turkey is located on a transitional zone. The reason for this transition zone is that Turkey has various pressure systems and types of air coming from polar and tropical zones. It is also important that the complexity of topographic features of country. Since Turkey is in a region that provides transitions between tropical and polar regions, it cannot be said that meteorological events are as stable as tropical and polar regions. Turkey will be affected by the negative aspects of global warming (especially weakening of water resources, forest fires, drought and desertification and ecological degradation). The country is among the countries in the risk group in terms of the potential effects of global warming.

The projected area of Turkey is 77,945 million hectares. 28,054 million ha of this area is agricultural land. 25,753 ha of this area is irrigable. However, due to technical and economic reasons, the amount of land that can be irrigated with surface and underground water resources is

Table 4 Land use status of dam and HEPP facilities in Artvin provincial borders (Yıldırımer 2013)

		Muratlı Dam	Borçka Dam	Deriner Dam	Artvin Dam	Yusufeli Dam	Bayram Dam	Bağlık Dam	Total (ha)	%
Stand Map	Settlement Areas	-	-	34,8	3,7	24,1	0,1	-	62,7	0,77
	Agricultural Areas	159,4	167,2	469	60,4	1104	82,9	1	2043,9	25,12
	Forest and Natural Ar.	41,5	437,3	1945,7	345,9	1974,2	262,5	35	5042,1	61,97
	Water Masses	225,2	424,7	221,5	-	116,7	-	-	988,1	12,14
CLC Map	Settlement Areas	-	69,7	-	-	26,9	-	-	96,6	1,19
	Agricultural Areas	11,5	26,2	535,6	66,2	1107,1	19,4	-	1766	21,78
	Forest and Natural Ar.	45,9	95	1679,6	145,6	1788	326,1	36	4116,5	50,59
	Water Masses	368,7	838,3	455,5	198,2	297	-	-	2157,7	26,52
	TOTAL (ha)	426,1	1029,2	2671	410	3219	345,5	36	8137	100

8.5 million ha. Currently, 4.9 million hectares of this area can be irrigated and construction of new facilities is required for the remaining 3.6 million hectares of agricultural land to be irrigated in the coming years. According to 2002 DSİ data (DSI 2017), it is seen that the total water use in Turkey is 40 billion m^3 / year, with 33,90 billion m^3 of surface water and 6,23 billion m^3 of groundwater per year in Turkey. This figure shows that less than half of the economically usable water potential (about 110 billion m^3/year) is used (Fakio 2012).

3.2 Land use changes in the basin

The water was kept at Muratlı Dam on 14/03/2005 and the first energy production was realized on 28/03/2005. A total of 426,1 ha area was flooded with Muratlı Dam as a result of the overlaps of the maps. When the characteristics of the land are examined, it is seen that the greatest change is in agricultural areas other than water-qualified areas. The reason why the water expressed part is the highest value is that the river bed covers a large area (Table 4). Borcka Dam completed the water catch in 2006. According to the obtained values, a total area of 1029 ha was flooded. When the maps are examined, it is seen that the highest value of underwater areas is forest land with 43%, and the lowest value is agriculture land with 16%. Deriner Dam, which has the highest dam of Turkey, opened in 2012. Approximately 2671 hectares of land have been flooded. When the maps are examined, it is seen that the largest area of underwater areas is forest area with 73% and the smallest area is water area with 8%. The construction of Artvin Dam and HEPP Project started in 2011 and started to hold water in 2015. A total of 410 hectares has been flooded. These areas are forest areas with 83% and residential areas with 1% according to stand map. Yusufeli Dam and HEPP, which will be the largest dam on the Coruh Basin and started construction in 2013, will flood an area of approximately 3219 hectares when it completed. When examined according to the stand map, it is seen that the largest area of underwater areas is in forestland with 62% and the smallest area is settlement area with 0.8% (Yıldırımer 2013). CLC MAP is a kind of land cover map (CORINE) developed by the Ministry of Forestry and Water Affairs.

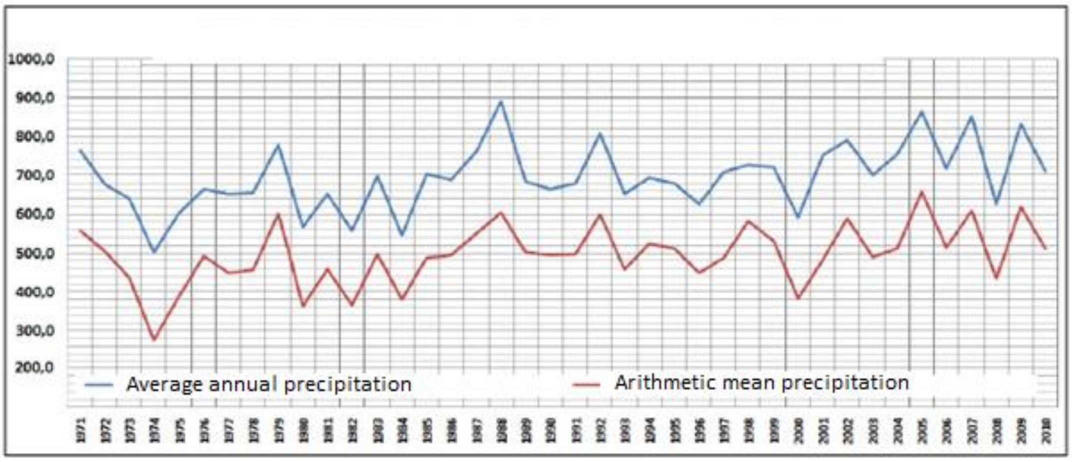


Fig. 4 The average annual precipitation and arithmetic mean precipitation change of the Coruh basin (Kayhan and Alan 2012)

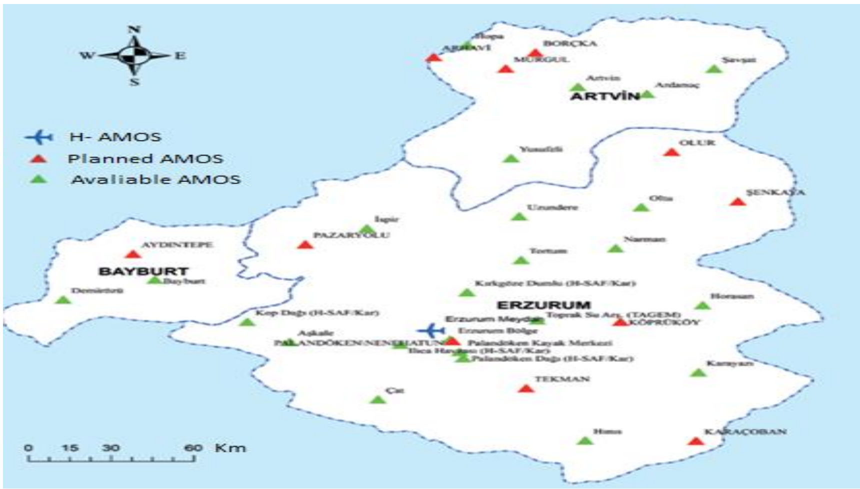


Fig. 5 Automatic meteorological observation station (AMOS) in Coruh Basin

3.3 Climatic effects in the study area

Depending on the varying rain rates, it is not clear exactly how the amount of superficial water flow will change, but records from past years show that every 1 ℃ rise in temperature will cause a 4% increase in global surface water flow. If this projection is applied to precipitation and evaporation, it is predicted that the global surface water flow will increase by 7.3% by the end of this century (Goudie 2006). That is, if a region receives more precipitation and more surface water flows, the probability of flooding this region will increase. Due to climate change, rising seawater levels lead to erosion, flooding and salt-fresh water mixing. Turkey is not a sensitive area in this regard, but for the Mediterranean and the Black Sea in the past century, the increase in sea level has reached 12 cm. The losses due to coastal erosion on the Turkish coast are manifested as a 6% loss in GNP (Demirkesen *et al.* 2008).

When the data are analyzed for five meteorological stations in the Çoruh basin, it is seen that the arithmetic mean of rainfall amounts is 495,1 mm/m^2 and the areal mean value is 695,9 mm/m^2. As can be seen from the graph showing the distribution of annual average data, there is a serious difference of 200.7 mm/m^2 on average between the area mean annual precipitation and the arithmetic average in the basin (Fig. 4) The meaning of such a large difference between the two means is the discrepancy between the station distribution and the precipitation regime. Moreover,

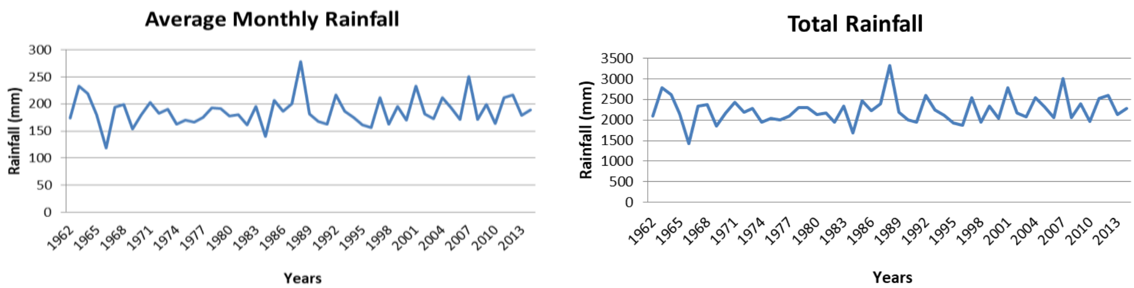


Fig. 6 Average monthly and total rainfall amount at Hopa Station

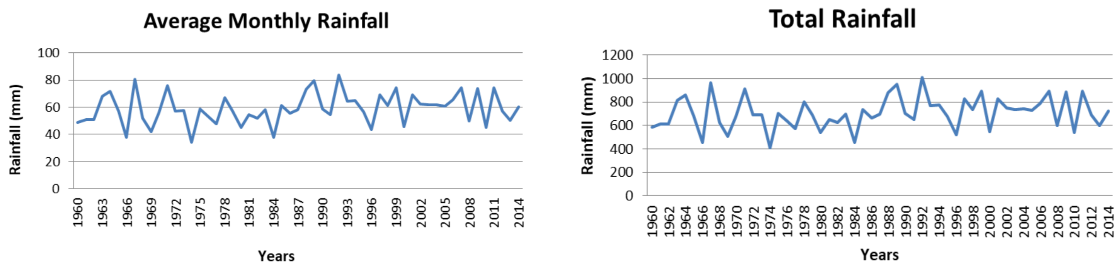


Fig. 7 Average monthly and total rainfall amount at Artvin Station

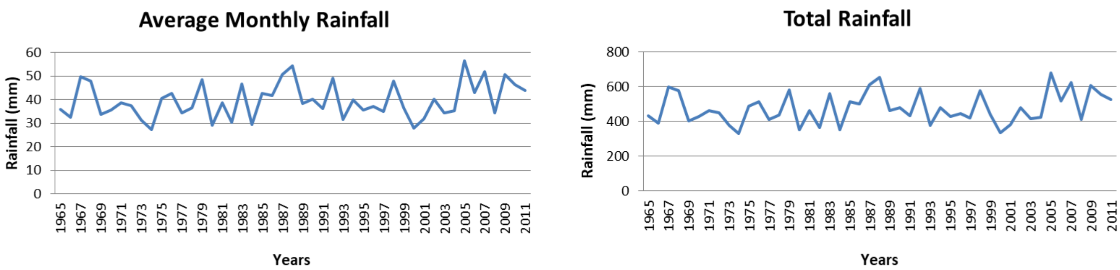


Fig. 8 Average monthly and total rainfall amount at Ispir Station

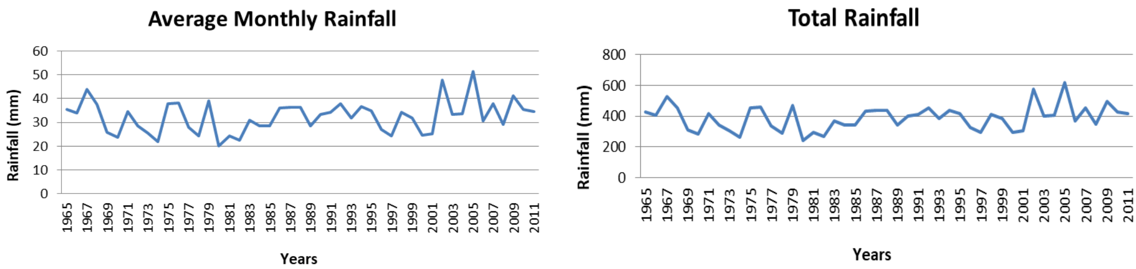


Fig. 9 Average monthly and total rainfall amount at Oltu Station

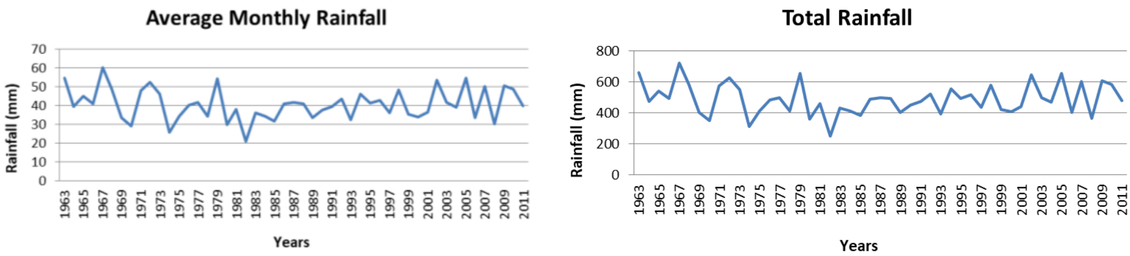


Fig. 10 Average monthly and total rainfall amount at Tortum Station

there is a very serious increase in the annual average rainfall amount of the basin compared to the annual average rainfall amount in Turkey (Kayhan and Alan 2012).

The water flow of the Coruh River varies according to the season. Because of the precipitation of snow, there is heavy flow between March and June. In summer, the flow is low due to precipitation. 85% of the total annual flow is the current from March to July. The Coruh River is the fastest flowing river of the country and its summit peak in May (1.529-1.569 m^3/s. The average discharge before leaving Turkey's borders is 192 m^3/s. The annual average flow volume is 6.3 billion m^3 and the total height to be energy produced is 1420 m.

In the last 10 years, 5 Automatic Meteorological Observation Station (AMOS) have been established in Artvin (Artvin Center, Hopa, Ardanuç, Savsat and Yusufeli). 13 AMOS was established in Erzurum (Central, Hinis, Horasan, İspir, Oltu, Tortum, Palandöken, Uzundere, Aşkale, Çat, Karayazı, Narman and Pasinler Soil Water Research). In Bayburt, 2 AMOS (Central and Demirözü) was established (Fig. 5). In the forthcoming period, 3 units in Artvin, 7 units in Erzurum and 1 unit in Bayburt are planned to be established.

The most regular and long-term measurement stations among the current monitoring stations were examined in order to examine the effects of completed dams on rainfall in the basin. It has been noted that the selected stations are located upstream and downstream of the zone. Artvin AMOS located in the middle point of the dams completed on the project and Hopa AMOS located in the downstream of all of them are examined. In addition, the values of Ispir, Tortum and Oltu AMOSs which are downstream of the all dams having been examined (Figs. 6-10). The data from 1960 to 2014 were assessed at the observation stations.

When the total and monthly mean rainfall amounts of the 5 large stations in our study area are examined, small changes are observed in the amount of precipitation since the dam reservoirs begin to fill up. When the graphs are examined, it is seen that the average rainfall has increased in the last 10 years although there is not a significant increase in the total amount of rainfall. Since 2005, the first dam started to fill, it is seen that rainfall amounts do not have very extreme values and there is a certain range of rainfall. Especially, it is clearly visible at the Artvin station, which is at the center of the dams and most affected by the dam lakes. The same situation also appears in the graphics of other stations. It is clearly seen that the lowest rainfall values have increased considerably when the values before and after 2005 are evaluated.

3.4 Ecological effects

Coruh Valley is located in the Caucasus Hotspot where the richest region of the world in terms of biodiversity and one of the 34 most important Terrestrial Ecological Zones in danger. WWF

Fig. 11 Endemic species transport area and dam reservoir area

Fig. 12 Examples of plant species displaced within the scope of the project (Artvin Kampüs 2013)

(World Wildlife Conservation Foundation) has declared the temperate zone forests of the Coruh valley as one of the top 200 Ecoregions in Protection on Earth. The Deriner Dam area is located in the Çoruh Valley important plant area as well as in the North East Anatolian Plant Diversity Center (SWA.19 North East Anatolia). With the completion of the Deriner Dam, a dam lake of 26.5 hectares will be formed. A project has been developed and implemented by the Ministry of Forestry and Water Affairs to transport some endemic and rare plant species that will be inundated to suitable areas (Fig. 11).

It has been detected that 1 endemic cataract is spread in the world and in Turkey, 1 non-endemic cataract is spread in Artvin and only under Deriner Dam at the end of the project. In addition, it has been determined that a total of 16 plant species are at risk, 14 of which are endemic and 2 are non-endemic (Fig. 12). According to the data obtained from the area, the total number of

Fig. 13 Camili biosphere area

movable individuals for 18 plant species is about 200. In addition, new species, not identified in the project, have been identified and its samples have been collected. As a second step of the project, studies on the production of target species started on 25.06.2012. 18 plant species were removed and planted in 252 pots. These plants were left to grow in Artvin Coruh University (Eminağaoğlu 2011).

Plants that are dismantled and produced in sufficient quantity in the sera will be transported to the determined area between 200-650 m elevations as the most suitable place in terms of features such as altitude, soil, ecological structure in the village of Artvin, Salkımlı. This transport area is a place where you can see the dam body. This area can be considered as an observation point for observing crops for viewing. Especially viewpoints can be created for these species to be watched by the wanderer. At the same time, it is thought that many points of view can be created within the study area where many wild animals can be traced. Birdwatching activity may also be performed within the study area.

The species found in the Coruh Basin, which has an extraordinary and rich flora, are bay, thyme, linden, rosehip, cherry and forest rose flowers. A total of 1,864 plant species and 119 endemic species were identified in the basin. Considering that the Turkish flora contains more than 11,000 species, it can be said that about 17% of it is here. The Kaçkar Mountains National Park is home to a rich flora. There are endemic species in both the lower and upper flores. This is the only place in Turkey where the rhododendrons reach 3,000 m. Wild animals such as wild goat, wolf, gray bear, pig, fox, deer, marten, jackal, birds pheasant, hawk, falcon, mountain rooster live in Kaçkar Mountains which are rich in fauna. The Kaçkar Mountains are one of the rare places where the glaciations of the Pleistocene are visible together with the current glaciation. There are many glaciers, glacier lakes, glacier valleys, circuses and moraines in the region (Surat *et al.* 2015).

The first and only biosphere area of Turkey is Camili located in Çoruh Basin (Fig. 13). The Camili Basin was declared a biosphere reserve by the United Nations Secretariat of the UNESCO MAB (Man and Biosphere) Program on 29 June 2005. The Camili Biosphere Reserve Area, attracting attention with its rich water resources, is 25,258 hectares in size. In the basin, which has a rugged terrain structure, 1021 species of plants are spreading. Camili is defined as one of 25 continental “Ecoregions” in the World, defined by the International Environmental Protection Agency (CI), the World Bank (WB) and the Global Environment Facility (GEF). It is also monitored by the World Wildlife Fund (WWF) in the framework of the “High Value Protected Areas Project”. Camili is the largest natural aged forest ecosystem in Europe and Central Asia.

Camili Basin is part of the “Important Plant Area of the Karçal Mountains” which is one of Turkey’s 122 Important Plant Areas. In addition, Camili is the only place in which the Caucasian Bee breed remains without compromising its purity. For this reason, it has been taken under the scope of “Gene Protection Site”. The Karcal Mountains are one of the important habitats of birch chickens and hooked horned mountain goats. The black bear, which is under international protection, is among the fauna riches of the area.

Due to severe erosion in the basin, there is a risk that the completed, under-construction and planned dam reservoirs will fill up in short time and their economic life will decrease. Therefore, there is a need to conduct river basin rehabilitation work in the region. Coruh River Basin Rehabilitation Project has been prepared with the aim of managing natural resources, preventing erosion and increasing income levels of the people. The project will be implemented between 2012 and 2019 and includes Artvin, Bayburt and Erzurum. The budget of the project that 38,000 people in 156 villages will benefit is 145 million TL. Activities such as flood control, rehabilitation of forests, avalanche control, soil conservation, providing agricultural production support, improvement of living conditions of villagers, rehabilitation of rangeland rehabilitation and degraded forests, development of irrigation infrastructure, bee hive, fruit garden and greenhouse facilities will be carried out within the scope of the project. The Çoruh River Basin Rehabilitation Project, which is also aimed at promoting and supporting solar energy systems, has also added functional planning of forest areas, development of national parks and hunting-wildlife, planning and development of ecotourism.

4. Conclusions

The water masses in the dam lakes cause cooler summers and milder winters around the dam due to their thermal properties. At the same time, it causes a significant difference in the direction of dominant wind in the region and a significant increase in wind intensity. Because of the different water vapour pressures of water and air, large amounts of moisture transfer from the lake surface to the land. With the increase in air humidity, there are large increases in fog, frost, snow and rain in the region.

In Turkey, climate-related risks and impacts in the water sector are drought, flood, salinization, and precipitation distribution. Changes in water resources also affect many sectors such as agriculture, health, energy and infrastructure. Coruh Basin Conservation Action Plan has been prepared with the aim of taking a holistic view of all the resources in the Coruh Basin. The Action Plan was completed at the end of 2013. With the Action Plan, the general situation of the Coruh Basin, the hot spots in the basin, the water quality status and the factors affecting this situation have been determined and short, medium and long term measures have been presented to improve the existing situation.

It has been determined that there will be significant changes in the existing land use in the lake areas that will be built in Çoruh Basin due to the dams being constructed and to be constructed. A total of 8137 ha will be flooded if the reservoir areas of the dams are filled with water. The greatest proportion of these areas is found in forests, and the smallest proportion is in residential areas.

When the meteorological stations considered to be under the influence of the dam reservoirs and the lakes of the completed 4 large dams are examined, the average amount of rainfall shows a slight increase. It is also seen that the precipitation is more regular. If too many dams are considered to be built in the Basin, the actual impact will be more accurate after all dams have been completed. The consequence of climate change will be a lethal flood and soil erosion source for countries that will not be able to provide adequate infrastructure, while precipitation increases will not be a problem for countries with water storage, routing and distribution technology.

Turkey has developed a national action plan on climate change, along with the need to develop it. Climate change is monitored by a specialized ministry in many countries. Different aspects of climate change in Turkey are handled independently by various ministries and institutions and this leads to coordination problems. Therefore, it is necessary to keep the institutional and legal structure in mind. In principle, authorities should be fully identified among institutions playing a role in climate change and water management, and these powers should be complementary to each other, not contradictory or overlapping.

References

Akpınar, A., Kömürcü, Mİ. and Kankal, M. (2011), "Development of hydropower energy in Turkey: The case of Coruh river basin", *Renew. Sustain. Energy Rev.*, **15**, 1201-1209.

Alam, M.K., Mirza, M.R. and Maughan, O.E. (1995), "Constraints and opportunities in planning for the wise use of natural resources in developing countries: Example of a hydropower project", *Environ. Conserv.*, **22**(4), 352-358.

Ang, B.W., Wang, H. and Ma, X. (2017), "Climatic influence on electricity consumption: The case of Singapore and Hong Kong", *Energy*, **127**, 534-543

Aras, E. (2012), "The effects of small scale hydroelectric power plants located in the eastern black sea basin in Turkey", *Energy Explor. Exploit.*, **30**(6), 999-1015.

Artvin Kampüs. (2013), "Artvin'deki barajlara yakın bakış", *Artvin Çoruh Univ. Bull.*, **3**(8), 4-13 (in Turkish).

Aydoğan, D., Kankal, M. and Önsoy, H. (2016), "Regional flood frequency analysis for Çoruh Basin of Turkey with L-moments approach", *J. Flood Risk Manage.*, **9**(1), 69-86.

Barrow, C.J. (1981), "Health and resettlement consequences and opportunities created as a result of river impoundment in developing countries", *Water Suppl. Manage.*, **5**(2), 135-150.

Baxter, R.M. (1977), "Environmental effects of dams and impoundments", *Ann. Rev. Ecol. Syst.*, **8**(1), 255-283.

Berkün, M, Aras, E. and Anılan, T. (2008), "Barajların ve hidroelektrik santrallerin nehir ekolojisi üzerinde oluşturduğu etkiler", *Türkiye Mühendislik Haberleri*, **452**, 41-48 (in Turkish).

Bozkurt, D., Sen, O.L. and Hagemann, S. (2015), "Projected river discharge in the Euphrates. Tigris Basin from a hydrological discharge model forced with RCM and GCM outputs", *Clim. Res.*, **62**(2), 131-147.

Canter, L. (1999), *Cumulative Effects Assessment in Handbook of Environmental Impact Assessment*, Blackwell Science Ltd., Oxford, U.K., 405-440.

Demircan, M., Demir, Ö., Atay, H., Eskioğlu, O., Tüvan, A. and Akçakaya, A. (2014), "Climate change projections for Turkey with new scenarios", *Proceedings of the Climate Change and Climate Dynamics Conference 2014*, Istanbul, Turkey, October.

Demircan, M., Gürkan, H., Eskioğlu, O., Arabacı, H. and Coşkun, M. (2017), "Climate change projections for Turkey: three models and two scenarios", *Turk. J. Water Sci. Manage.*, **1**(1), 22-43.

Demirkesen, A., Evrendilek, F. and Berberoğlu, S. (2008), "Quantifying coastal inundation vulnerability of turkey to sea-level rise", *Environ. Monit. Assess.*, **138**(1-3), 101-106.

DSI. (2017), *Turkish State Hydraulic Works*, <www.dsi.gov.tr>.

Dudgeon, D. (1995), "River regulation in southern China: Ecological implications, conservation and environmental management", *River Res. Appl.*, **11**(1), 35-54.

Eminağaoğlu, Ö. (2011), *Coruh Valley and Deriner Dam Draft Report on the Protection of Endemic and*

Non-Endemic Rare Plants in the Area to be Inundated with Water, Technical Report, Ankara.
Evans, J.P. (2009), "21st century climate change in the Middle East", *Climatic Change*, **92**(3-4), 417-432.
Fujihara, Y., Tanaka, K., Watanabe, T., Nagano, T. and Kojiri, T. (2008), "Assessing the impacts of climate change on the water resources of the Seyhan River Basin in Turkey: Use of dynamically downscaled data for hydrologic simulations", *J. Hydrol.*, **353**(1-2), 33-48.
Garipağaoğlu, N. (2012), "Role of geography in basin planning and basin planning in Turkey", *Atatürk Üniversitesi Sosyal Bilimler Enstitüsü J.*, **16**(2), 303-336.
Goudie, A. (2006), "Global warming and fluvial geomorphology", *Geomorphology*, **79**(3-4), 384-394.
Hemming, D., Buontempo, C., Burke, E., Collins, M. and Kaye, N. (2010), "How uncertain are climate model projections of water availability indicators across the Middle East", *Phil. Trans. Royal Soc. London A Math. Phys. Eng. Sci.*, **368**(1931), 5117-5135.
ICOLD (1997), *The Benefits of Dams to Society,* International Commission on Large Dams, United States Committee on Large Dams Newsletter, U.S.A.
Kayhan, M. and Alan, I. (2012), *Turkey Spatial Precipitation Analysis: 1971-2010*, Technical Report.
Ludwig, H.F. (1982), "Environmental aspects of multi-purpose reservoir projects in developing countries", *Water Sci. Technol.*, **14**(1-2), 269-288.
Maingi, J.K. and Marsh, S.E. (2002), "Quantifying hydrologic impacts following dam construction along the Tana River Kenya", *J. Arid Environ.*, **50**(1), 53-79.
MGM (2017), *Turkish General Directorate of Meteorology*, <www.mgm.gov.tr>.
Önol, B. and Semazzi, F.H.M. (2009), "Regionalization of climate change simulations over the Eastern Mediterranean", *J. Climate*, **22**(8), 1944-1961.
Özdoğan, M. (2011), "Climate change impacts on snow water availability in the Euphrates-Tigris basin", *Hydrol. Earth Syst. Sci.*, **15**(9), 2789-2803.
Sadler, B. (1996), *Environmental Assessment in a Changing World: Evaluating Practice to Improve Performance-Final Report*, International Study of The Effectiveness of Environmental Assessment, International Association for Impact Assessment/Canadian Environmental Assessment Agency, Quebec, Canada.
Sen, O.L., Unal, A., Bozkurt, D. and Kindap, T. (2011), "Temporal changes in the Euphrates and Tigris discharges and teleconnections", *Environ. Res. Lett.*, **6**(2), 024012.
Skoulikaris, C. and Ganoulis, J. (2017), "Multipurpose hydropower projects economic assessment under climate change conditions", *Fresen. Environ. Bull.*, **26**(9), 5599-5607.
Surat, H., Yılmaz, H. and Surat, B.Z. (2015), "A research on the potential use of ecotourism in Yusufeli and its environs", *East. Geograph. Rev.*, **34**, 61-88.
Toker, E. (2010), "Borçka ve Deriner barajlarının Çoruh havzasında neden olduğu arazi kullanım değişiminin ve arazi tahribatının irdelenmesi", M.Sc. Thesis, Artvin Çoruh University, Artvin, Turkey (in Turkish).
Toprak, F., Hamidi, N., Toprak, Ş. and Şen, Z. (2013), "Climatic identity assessment of the climate change", *J. Global Warming*, **5**(1), 30-45.
Williams, P.B. and Veltrop, J. (1991), "The debate over large dams: The case against; The case for", *Civ. Eng.*, **61**(8), 42.
WWF, (2017), <http://www.wwf.org.tr/>.
Yıldırımer, S. (2013), "Çoruh nehri üzerinde tamamlanan, inşası devam eden ve planlanan büyük barajların neden olduğu ve olacağı arazi kullanım değişimlerinin belirlenmesi", M.Sc. Thesis, Artvin Çoruh University, Artvin, Turkey (in Turkish).
Zeng, X., Zhao, M. and Dickinson, R.E. (1998), "Intercomparison of bulk aerodynamic algoriths for the computation of sea surface fluxes using toga coare and tao data", *J. Climate*, **11**(10), 2628-2644.
Zhao, Q., Liu, S. and Dong, S. (2010), "Effect of dam construction on spatial-temporal change of land use: A case study of Manwan, Lancang River, Yunnan, China", *Proc. Environ. Sci.*, **2**, 852-858.
Zhao, Q., Liu, S., Deng, L., Dong, S., Yang, Z. and Liu, Q. (2013), "Determining the influencing distance of dam construction and reservoir impoundment on land use: A case study of Manwan Dam, Lancang River", *Ecol. Eng.*, **53**, 235-242.

Zhao, S., Peng, C., Jiang, H., Tian, D., Lei, X. and Zhou, X. (2006), "Land use change in Asia and the ecological consequences", *Ecol. Res.*, **21**(6), 890-896

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