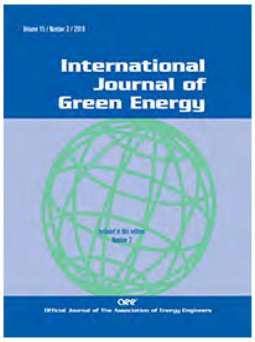

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A study on operation problems of hydropower plants integrated with irrigation schemes operated in Turkey

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ABSTRACT
In this study, Hydroelectric Power Plants, which have been built and integrated with irrigation schemes by the State Hydraulic Works which is a government agency and private companies in Turkey, have been examined. Technical, environmental, structural and social problems encountered during their operation have been analyzed, and appropriate solution proposals have been presented in the study for a sustainable irrigation and Hydroelectric Power Plant operation. Consequently, Hydroelectric Power Plants which have been integrated with irrigation schemes should be operated efficiently and they should be operated in attenuation with the environment. However, when hydroelectric projects are developed without preparing their necessary integrated basin management plans, then this will cause environmental, operation and maintenance, administrative, monitoring and evaluation problems. In order to ensure sustainability of hydroelectricity production and also in order to use water resources more efficiently for irrigation; it is very important to find permanent solutions to these problems.

KEYWORDS
Additional contracts; environmental problems; hydroelectric power plant; irrigation scheme; measurement facilities; operation problems

Introduction

Hydroelectric power is a renewable energy resource, which is based on the hydrological water cycle. Hydropower is considered as a natural, reliable, and a low-cost renewable energy production technology (Brown, Müller, and Dobrotková 2011; IPCC 2011). Hydroelectric power has been used for over a 100 years and it has become the main electricity production source in 55 countries of the world (IHA 2003). Despite its widespread use all over the world, only one-third of the global economic hydroelectric potential has yet been used (Karki 2008). Today, hydroelectric power, generated by large and small-scale hydroelectric power plants in the European Union (EU) represent 13% of the total electricity production. In this case, carbon dioxide (CO_2) emissions are to reduce by more than 67 million tons of a year (IPCC (Intergovernmental Panel on Climate Change) 2011).

Hydroelectric power can be obtained through a wide variety of project scales and types. Hydropower projects can be designed according to the specific site conditions and as per special needs. Since hydropower does not pollute or consume the water used in energy production, this vital resource is also left available for other uses as well (Kaygusuz 2011; Yüksel 2010). In particular, it is important to have a detailed study in the planning stage before developing energy projects. This is particularly essential for water structures, since these structures are designed to serve in the long-term period and have high investment costs. Thus, mistakes made about water source, site selection, and geological structure in the planning stage can cause major problems that cannot be eradicated even at the operation stage (Koç, Bayazıt, and Bakış 2016).

Total annual hydroelectric power potential of Turkey is 433,000 GWh, which is about 1% of the world's total hydroelectric potential. Considering the total hydroelectric power capacity of Europe, the share of Turkey is about 14%. About half of the total potential is technically utilizable, 38% (165 GWh/year) of this potential is economically utilizable, and 49% (82,036 GWh/year) of economic potential has been developed until now (DSI 2015).

In this study, Hydroelectric Power Plants (HPPs), built and then integrated with irrigation schemes by the State Hydraulic Works (DSI), as well as by private companies in Turkey have been examined. Technical, environmental, structural, and social problems encountered during the operation have been analyzed, and solution proposals have been presented to carry out a sustainable Hydroelectric Power Plant operation.

HPP facilities integrated with irrigation schemes

Hydroelectric Power Plants have been built the storage facility (dam), run-of-river, and run-of-canal integrated with irrigation schemes by State Agency and Private Companies, and they have been operated by Energy Production Anonym Company (EPAC), which is a state agency or by private companies with various financing models such as Built-Operate-Transfer (BOT), 4662 law Content or Operation Right Transfer (ORT). Some statistical values are provided in Table 1 related to the organizations building and operating the HPP, and the location where the HPP is established, as well as the installed power and production capacity of HPP. A total of 75% of the operated HPPs in Turkey were built by private companies. Based upon the location where HPPs are built, it can be stated that the 73%

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of the HPPs are canal-type HPP, 7.9% are run-of-river type and 19% are dam-type HPPs, while lake-type HPPs constitute 0.36%. HPPs built by private sector with various methods have 10,288.53 MW of total installed capacity and 37,884.55 GWh/year of total production capacity. The number of HPPs that have become operational in May 2015 are 555, total installed power is 22,862.51 MW, and production capacity is 82,035.97 GWh/year. This amount constitutes 49% of the country's hydropower potential that can be developed economically (DSI (State Hydraulic Works) 2015a).

While total installed power of HPPs, which have become operational in 2000, was 1,117.2 MW, it has increased to 16,926.80 MW in 2012. Hydroelectric energy power installations in Turkey have increased over the years. In the 1970s, installed power of HPPs was 725 MW, in 2005 12,906 MW, and in 2010 it was 15,831.20 MW. Of the 281 HPPs operating in Turkey between the years 2002 to 2012, the installed power of dam-type plants was 13,318.9 MW (79%) and of run-of-river type plants was 3,607.9 MW (21%) (DSI 2015a). In those years, canal-type HPPs that which were integrated with irrigation in Turkey were very less or even non-existent. Southeastern Anatolia Project (SAP) contributes to Turkey's hydroelectric power generation. Construction of 13 HPPs was completed in 2015. HPPs operated in the region have an electricity production capacity of 20.6 billion kilowatt-hours per year. The area opened for irrigation is 474.528 hectares (DSI 2016). Therefore, integrated operation of irrigation and energy facilities in the SAP region is very important.

Almost half of the hydroelectric energy production in Turkey is generated from the HPPs built by the private sector. Some statistical values of HPPs integrated with irrigation schemes are given in Table 2. In Turkey (based on the data available in 2015), the number of HPPs integrated with irrigation is 81. The HPPs integrated with irrigation are built as dam and canal plants. These plants constitute about 15% of the total number of built HPPs and 22.5% of all hydroelectric installed capacity. The 22.3% of hydroelectric energy produced annually are provided from HPPs, which have been integrated with irrigation.

Hydroelectric Power Plants integrated with irrigation usually occur from the canal and dam type HPPs in Turkey. The purpose of canal and dam HPPs is to provide a clean, renewable energy source that is locally controlled. Energy of dams integrated with irrigation is taken by HPP, then water is provided for irrigation, and the energy is taken in once again by the canal HPP built on irrigation scheme. A significant unused opportunity for hydroelectric power development lies in capturing power from flows within irrigation canals. Canal HPP projects are developed by DSI and private companies, and operated together by Water User Organizations and private companies. Some canal HPP projects are dependent on the dams. Water released from the dams in this type of plant is diverted to the canal by regulator, and energy is produced with a regular amount of irrigation water during the irrigation season, as well as there is the possibility of production in accordance dam operation program during the winter. Canal HPP only uses normal irrigation flow. The HPP projects are built and they are integrated with the present irrigation scheme and irrigation remains its primary purpose with all other uses playing secondary roles. The private company operating the HPP has no control over operation of irrigation canal. Canal HPP project diverts irrigation flow from the canal, passes them through the power plants, and then returns the water to the canal immediately below the power plants. Irrigation schemes are managed by Water User Organizations (Irrigation Associations, Irrigation Cooperatives, and Municipalities) to prevent the interference with irrigation operations. Hydroelectric power cannot generate during the peak irrigation period depending on water requirements of crops planted and deficiency of water resources in the irrigation project. According to Koç (2011), canal HPPs can be built economically due to its short investment term (1–3 year), and also because they have lower investment costs (1,200–1,800 US$/kW) compared to large hydropower plants. However, the HPPs can still be built only by financially strong companies. This approach allows to reduce construction costs and to accelerate the project completion compared with construction at undeveloped sites. An advantage of canal HPPs is that environmental impacts are minimal as compared to the typical large hydropower projects.

Table 1. HPPs under the operation in Turkey (DSI (State Hydraulic Works) 2015).

	HPPs under the operation (May 2015)						
	Built Location of HPPs (Number)						
Groups of HPPs	Canal HPP	Run-of-river HPP	Lake HPP	Dam HPP	Total	Installed power (MW)	Production capacity (GWh/year)
EPAC	12	2	1	46	61	12,473.98	44,151.42
ORT	2	0	0	1	3	570.12	1,680.00
PRIVATIZATION	49	5	1	7	62	286.07	1,110.42
BOT	9	1	0	4	14	849.8	3,293.01
PRIVATE COMPANY	331	36	0	48	415	8,682.54	3,1801.13
TOTAL	403	44	2	106	555	22,862.51	82,035.97

Table 2. HPPs integrated with irrigation facilities (DSI (State Hydraulic Works) 2015).

	Canal HPP	Run-of-river HPP	Lake HPP	Dam HPP	Total
Number	36	1	1	43	81
Installed power (MW)	345,63	9,3	15,36	4778,62	5148,901
Production capacity (GWh/year)	1383,90	55,00	48,00	16807,06	18293,96
Percentage share (number) (%)	0,13	0,00	0,00	0,16	0,30
Percentage share (installed power) (%)	0,02	0,000	0,001	0,209	0,225
Percentage share (production capacity) (%)	0,02	0,001	0,001	0,205	0,223

Problems of HPP facilities integrated with irrigation schemes

Hydroelectric Power Plants have to be operated in peace and in attenuation with the environment. However, HPP projects developed without integrated basin management plans lead to technical, environmental, economic, and social problems. HPP projects and the signed agreements are faced with various problems from the planning stage to the operational stage. These issues can be grouped as "*Water Use Right Agreement (WURA)*", feasibility reports, investment period (construction phase), and problems related to the operation

Table 3. Problems in the operation phase of HPPs integrated with irrigation.

1.Environmental problems
Environmental flow (ecological balance flow), fish passages, water quality and water pollution, solid waste, sediment transport, air, soil and noise pollution, various interventions
2. Operation and maintenance problems
Dams, regulators and canal operation programs, operating regimes of consecutive HPP facility, additional contracts, share separation, repayment of investment, contribution shares, basin hydrological monitoring and evaluation and control service costs, measurement facilities, expenses
3. Administrative problems
To establish of Chief Engineering in regions, The distribution of duties and powers, legal regulation, to keep education and qualified staff
4. Monitoring and evaluation problems
Measurement facilities, monitoring and evaluation studies

period. Problems, encountered at the operation period of HPPs integrated with irrigation are examined and presented in Table 3. Most common problems of HPPs operated as integrated with irrigation schemes are the operating regimes of dam and canal plants, additional contracts and implementation, establishment of flow measurement facilities, monitoring the allocated water for environmental flow, implementation and determining the rate of share for the common water structures, maintenance-repair works and sharing of costs, fish passages, sediment transport, and administrative troubles.

Environmental problems

The most well-known environmental threats of the HPPs in operation are ecosystem degradation, changes of water chemistry and physical habitat, additions and removals of species (Malmqvist and Rundle 2002), decrease in sediment transport, reduction of wetlands, damage on freshwater habitats and organisms (Kingsford 2000), changes in natural flow regimes, and decrease and extinction in fish populations owing to the prevention fish migration and moves (SHERPA 2010). HPPs have led the public to develop an unfavorable opposition, because of some negative impacts on environment while they are generally preferred in terms of renewability, emergency management, and decrease in flood risk. Environmental problems encountered in the operation stage of HPPs, which are integrated with irrigation, are given below.

(1) Water Use Rights at the upstream and downstream of the HPPs have not clearly taken part in the agreements. Water users have been faced with a major problem between the point that water is diverted from the canal with a diversion structure (regulator) or dam and at that point the water has reached the river bed after the completion of the energy production at the HPP. This intermediate basin can be 5–10–15 km long and it may even extend as long as 50 km. In the basin, one of the major problems is how to control and organize the amount of water which is not allocated formally for public irrigation, along with managing drinking water and environmental flow (natural life water). Although water utilization in the basin is identified in the "*Downstream Water Rights Report*", there are some problems in the practice.

(2) Rate of necessary environmental flow to continue the wildlife with flora and fauna is defined as at least 10% of the average flow amount in the last 10 years of project for the downstream of dam or diversion structure to which HPP belongs. However, this rate is never sufficient in some river beds, since the water is taken by other projects or public irrigations at the downstream or is released intermittently. Thus, the habitat structure around the stream is faced with extinction. Therefore, the rate determined as 10% of environmental flow should be redefined with a variety of habitat simulation models. The allocated water for public irrigations should be left uninterrupted to downstream from the dams or diversion structures. The amount of required water to ensure the sustainability of ecosystems and ecological life should be determined by scientific methods. Tennant method which is used more widely than the other methods is also the most commonly used method in Turkey (Tharme 2003). Tennant method is generally used in rivers and streams with a slope of less than 1% (Mann 2006) and there are differences in usage in each area or country (Acreman and Dunbar 2004; Orth and Maughan 1981). Value of environmental flow is considered as between annual maximum flow and annual minimum flow in Austria. There is no standard method in England; consequently, the criteria are defined by the conducted experiments in the field conditions before license is given. The value is considered as 1/3 of the average summer flow in Greece (ESHA 2010). It is generally more than 1/10 of annual average flow, but more than 1/20 of annual average flow for the high flow rivers, larger than 80 m^3/s in France. This value is between 1/3 and 1/6 of the average minimum flow in Germany (SHERPA (Small Hydro Energy Efficient Promotion Campaign Action) 2010). At the beginning of the 2000s, in Turkey, the value of environmental flow was 1% of annual average flow. It was then later increased to 2.5%, then to 5%, and it is now 10% of average annual flow at present. But, to determine a standard level for a minimum amount in stream flow is problematic, as it ignores the various properties of streams and rivers. As per the specialists studying in Turkey, amount of flow needed for sustainable ecosystems of rivers should be 40–60% of the average annual flow (Şekercioglu et al. 2010; TMMOB 2011). For the HPPs researched in West Mediterranean and Buyuk Menderes Basin in Turkey, the amount of water released for the ecological life is 10% of the average annual flow of the river and stream on which the HPP is built (Koç 2012). This rate should take place in Feasibility Report, Environment Interaction Assessment Report, and WURA with Water Rights Report in terms of time and the amount of water needs, and should be measured easily and correctly. It should be made necessary that HPPs not practicing

this amount or users interfering with this flow should face criminal proceedings.

(3) Fish passage is not only a problem of HPP integrated with irrigation schemes but also of all hydropower. While structural and functional fish passages should be at the storage facilities and regulators, in many of the facilities there are no fish passages. In order to decide on the construction of fish passage, there is a need for the information such as their migration period, available fish species, as well as the fish size belonging to the stream where the HPP is to be built. This information should be included in the feasibility reports. Furthermore, the manufactures belonging to the fish passage structures should be taken place as detailed as possible in the feasibility report. According to the provisions stated in the article 22 of *"Fisheries Law 1380"* of EU environment acquis and in the article 8 of *"Fishers Regulation"* published in the Official Gazette No. 22223 in 1995; in Turkey, structural and functional fish passage structures should be constructed in storage and diversion structures. In projects where the topography is appropriate, natural-type fish passage should be primarily preferred. As per Larinier (2008), in France, for reasons such as insufficient release of adequate water, even the most convenient fish passages create some delay in fish migration and HPP turbines cause fish deaths. According to Larinier, Travade, and Porcher (2002), fish pass used the most frequently for small-scale HPPs is the pool-type fish pass. A study carried out by Tarrade et al. (2008) reported that vertical slot fish passage is underway to characterize flow in terms of flow pattern, speed, turbulence. Turbine types which do not harm the fish should be preferred. In addition, entrance of main canal and penstock should be placed with filter, sound and light repellents, and trash rack to prevent fish passage. Trussart et al. (2002) has reported that fish-friendly turbines, and filter systems should be used to prevent fish and other water organisms from being harmed by getting into the used water in HPP. Further, the functionality of the existing fish passage should be observed, and the problems should be resolved.

(4) Amount and behavior of sediment that negatively affects the environment and energy production at the upstream and downstream of HPPs should be identified. In order to determine sediment behavior, water, air, soil, noise pollution, and water quality; the private company and DSI should conduct studies jointly every 3 years, and the final reports should be arranged and take the necessary precautions. Furthermore, an article suitable for this case should be added to the WURA.

(5) Company, Water User Organization and DSI should work jointly on the issues as to where and how to dispose and to store of each type of waste arising and excavation according to environment legislation during operation and construction of HPP projects foreseen to be implemented the integrated with irrigation schemes. Technologies which will be applied should be determined for the natural recycle.

(6) Water User Organizations, other stakeholders, and local governments should work in cooperation in order to create parks and recreation areas such as the afforestation of walkways, green space corridors at the Regulator, dam lakes, canals, service roads edge, and the expropriated areas including common facilities.

Operation, maintenance, and management problems

(1) After evaluation and collection of data on the hydrological and meteorological (flow, rainfall, snow, evaporation, lake levels, reservoir inlet, and outlet flows) of the operated dams and dam operating characteristics (maximum and minimum operation level, flood control curve, level-area-volume tables, level-evaporation tables, reservoir active volume changes, sectoral water demands); total water requirements are determined for the energy, irrigation and drinking water, and annual dam operation programs are prepared by the estimation of the input flows. Dam operation programs consider the anticipation of no disposal or disposal in the least amount possible of water from dam spillway to provide the flood control according to the potential of the water sources that feed the reservoir. Electricity Generation Anonym Company (EGAC) and Turkey Electricity Transmission Anonym Company (TETAC), which has the mandate to consider the energy and water demands of the country, ensure regularly the distribution and sharing of the generated energy. However, operation program for canal HPPs is not prepared as energy production is based on irrigation inflow. There are major problems arising from the implementation of operation programs at the consecutive HPPs or HPPs integrated with irrigation when energy production is actualized at the puant hours without releasing enough water to the downstream except during puant hours when the generated energy is sold with high prices. This situation prevents the operation conditions of downstream projects, and disrupts particularly the operation of irrigation projects at the downstream. In addition, since some HPPs located at the downstream are not designed with the capability to use the water released at the puant hours from HPPs at the upstream, all energy of the released water at puant hours cannot take and the left water leaves the riverbed. On the other hand, to suddenly release the accumulated water to the riverbed at the puant hours can lead to scour and change of shapes of riverbed as well as to cause adverse events on natural life in the riverbed. Therefore, to comply with scrupulously dam operation programs prepared for dams, to prepare operation programs compatible with irrigation for canal HPPs, to measure of water released for the stakeholders, to make gradually flow increase and decrease if HPP is operated at the puant hours, to ensure safety of life and property at the downstream, to take

protective security measures, are very important for effective and safe HPP operation.

(2) "*Downstream Water Rights Report*" (for dry stream bed between the point where water is diverted to the canal from regulator or dam and the point where water has reached the river bed after the completion of energy production) and "*Water Rights Report After Tail Water*" (for areas situated at the downstream of tail water outlet after energy production) should be prepared for each HPP. These two reports should also be included in the economic risk analysis. Therefore, this provision should be put into the new WURA regulations. Economic risk analysis and preparation of water rights reports after tail-water have not yet been implemented. These reports, containing an inventory and regulation regarding the amount and timing the water of non-allocation for public irrigation, drinking water, water mill located at the upstream of diversion or dams, should be prepared and implemented as soon as possible. In particular, determining the cropping pattern, crop water requirements, and irrigation areas of public irrigation projects, the needed water should be provided in the social state concept. Environmental flow, ancient water rights, and amount of water allocated are descripted in the "*Water Rights Reports*" *and* "*Environment Interaction Assessment Reports*" of canal and dam HPPs; however, for the projects not requiring *Environment Interaction Assessment Reports* preliminary, the ancient water rights, amount of the allocated water, environmental flow should be released to the downstream of river bed without interruption.

(3) Private companies, operating the HPPs built on irrigation canal and dam and Water User Organizations must make "*Additional Contract*" due to the provision of article 32 of WURA. Due to this provision, "*Additional Contract*" must be made between DSI, Private Company, and Water User Organization. The "*Additional Contract*" reveals the principles such as payment of the designated value, who will make the necessary works under the DSI coordinator, the rate of share for each stakeholder (Koç and Bayazıt 2015), completion of the final accounts until the end of the year, and who will make the operation, maintenance, repair, and renewal of facilities built by DSI. Furthermore, periods (months) of irrigation and/or energy production, and priorities are identified with the "*Additional Contract*" (Koç 2011, Koç 2017). Therefore, in order to avoid confusions which can arise between irrigation service and energy production, "*Additional Contract*" must be signed between managers of the company and Water User Organizations.

(4) Some HPP companies and Water User Organizations do not accept to participate in operation and maintenance costs of common facilities (regulator, dam, irrigation canal, and other structures) owing to the fact that the share segregation is made injustice to their advantage and/or redefined of the share rates. In common facilities, where share segregation has not yet been determined has caused major problems on the accrued and collection of operating and maintenance costs and recovery of investments. Therefore, revision of the share segregation and calculation of shares not yet determined should be actualized as soon as possible. Furthermore, stakeholders should know that share rates are calculated to the gained benefits during the lifetime of the facility, and not according to the rate of water used for energy and irrigation.

(5) Interventions should not be made to disrupt the flow security of water in the river and stream bed. Stakeholders should strive together to discipline the public irrigations and to prevent the uncontrolled water use that disrupts the flow order of the river and stream. Also, vandalism causes an important damage for common facilities. Therefore, stakeholders should cooperate for the solution of the problems and show the necessary attention to the implementation of criminal sanctions about acts in violation.

(6) Turbine flow used in HPPs integrated with irrigation should be designed to comply with the required flow for irrigation. During the irrigation period, the water released from the dams is primarily taken for energy and then used for irrigation services. Determining the flow rate to be used in Basin General Irrigation Planning prepared by stakeholder participation in the basin, the maximum and minimum turbine flow of dam and canal HPPs should be taken into account (Cap-Net 2008; Koç, Özdemir, and Fayrap 2010). Approaches based sector (only irrigation or energy) for water resources were influential in the past and still continues its activities. This approach leads to division and lack of coordination in the management and development of water resources (Cap-Net 2008). All planning studies to be carried out related to water resources in the basins, Turkey should be based on determining the existing water source and being able to make correct calculations for future, collecting data using appropriate methods and presenting the service of user.

(7) Hydroelectric Power Plants built in the basins are closely related with irrigation schemes. Particularly, at the HPPs integrated with irrigation schemes, firstly, the energy of water released from dams is taken and then the water is released back to the irrigation schemes for irrigation services. Thereof, the overlap of the flow released from dams to irrigation and the flow used in HPP should be considered as General Basin Irrigation Plans are prepared. Koç (2012) stated that operation of canal HPPs integrated with irrigation is very important in terms of irrigation and energy production. In order to maximize hydroelectric energy production and irrigation revenues, it is necessary that irrigation schedules prepared for irrigation schemes in basins should also take into consideration the energy production conditions. Koç (2011, Koç 2017) stated in his studies that selecting of turbine flow based on the distribution in irrigation season and amount of irrigation water required during irrigation season and suitability of irrigation canal capacity on which canal HPP is operated maximizes the energy production.

Administrative problems

(1) Necessary measures should be taken to remove the multi-headed institutional structure that creates confusion of authority among institutions. The most effective way to achieve this would be by having DSI as the main planner, decision maker as well as the supervisory authority in water resources management. DSI should be the only competent authority on the allocation of water in Turkey.

(2) The necessary legislative studies should be made urgently for the implementation of all kinds of inspections and application of sanctions in the planning, construction, and operation phases of HPPs. The duties, powers, and responsibilities of the relevant institutions should be clearly defined. A "*River Environment Management and Control Program*" should be established for each river and its surrounding and the program should be applied carefully by the relevant units.

Monitoring and the evaluation of problems

(1) Measurement facilities (Flow Observation Station), which are required to determine amount of the used water for energy, for irrigation, for drinking and potable, for environmental flow, should be combined with remote sensing systems (Supervisory Control and Data Acquisition SCADA). The installation cost of these facilities should be met by the stakeholders according to the DSI criteria (Koç, Bayazıt, and Bozkurt 2014), and the necessary studies for instant monitoring (real-time) should be started by DSI Regional Directorates and DSI General Directorate.

(2) Coordinated studies should be conducted among the relevant units for cases such as the insufficient number of measurement facilities used for determining the amount of water released for irrigation, energy, and environmental flow, no installation in proper sections of measure facilities, and for insufficient measurements by the measurement staff. Also, in the areas where the projects of irrigation and energy will be executed, there must be planning that takes integrated basin management plan into account (Koç, Bayazıt, and Bozkurt 2014). Integrated basin planning should be incorporated with various occupational disciplines, their representatives, local governance, and the civilian organizations. During the project's feasibility analysis, DSI should make decisions based upon integrated basin planning, not based upon only the project itself. The present situation in the basins should be considered and the possible improvisations should be determined and executed. General Basin Irrigation Plans should be prepared for the studied basins, and should jointly consider the other issues related to the integrated river basin plan. When the studies carried out in the developing countries take account of technical, social, and economic limits, they should also serve the purpose of increasing the awareness of the water users, farmers, and other stakeholders for environmental reactions (Koç 2015; Koç, Özdemir, and Fayrap 2010). Chen et al. (2016) state that good practices, security precautions and self-assessment measures have been developed by interested parties to reduce environmental and social risks in the hydroelectric power generation process. Sustainable basin management should come hand in hand with sustainable natural source usage and urban development in order to reduce poverty. Since initially, the energy of the water released from dams is taken, as a result this helps to achieve the optimum efficiency in energy production and in irrigation services. General basin irrigation plans should be prepared by taking into account turbine flow rate, the puant hours when energy requirements and energy prices are higher than other hours, as well as the irrigation water requirements calculated according to the crop water requirements for irrigation areas (Koç 2012). In addition, the length of irrigation season, characteristics of irrigation schemes integrated with HPPs (Koç 2007), as well as the amount of water to be released for ecological purposes should also be considered as well.

(3) The company should send the operating reports (daily, monthly, yearly) of the energy generated at the HPPs to the relevant departments of DSI. Also, annual activity reports which will be prepared at the end of each year and forecast reports should be sent to DSI until the last day of the first month of the year. These reports should then be forwarded to the Operation and Maintenance Department of DSI General Directorate after being approved by the DSI Regional Directorates.

(4) Software program, based on Geographic Information Systems (GIS) launched for monitoring and evaluation should be completed and presented to the usage (Koç, Bayazıt, and Bozkurt 2014).

Conclusion and recommendations

Until 2015, 81 HPPs, which are integrated with irrigation schemes in Turkey, were built. Therefore, operation of HPPs which has been built and integrated with irrigation schemes by DSI and private companies is very important nowadays. The operated HPPs encounter with technical, environmental, social, and structural problems. When these problems are solved or reduced, the HPPs integrated with irrigation schemes are operated more efficiently and more harmoniously with the environment. The allocation of water, the allocation ratio, determination of the operating policies, monitoring, control, and audit activities for HPPs are within the areas of responsibility of DSI General Directorate in Turkey. However, the provision of harmony and coordination among EPAC, TETAC, Ministry of Environment and Forestry, Environment Provincial Directorates, Private Companies, and the relevant organizations are very important for improving the energy efficiency and to solve problems that may arise.

When the production share of hydroelectric power is increased; it is possible to reduce the dependence on other countries in energy, and to implement a water-energy operation which is undisturbed, understandable, auditable, and sustainable. Necessary studies should be performed to reduce, remove or to compensate the negative effects of HPPs on river ecosystems by methods used in the world. National HPP guide books identifying the operation stage of HPPs should be prepared and presented to relevant units.

A national method should be developed for determining the amount of water to be released to the river or to stream beds for ecological purposes. While this method is determined, water resource characteristic and the properties of the ecosystems surrounding the water resource should be taken into account and it should rely on scientific studies. The distribution process and timing of the environmental flow, the choice of the responsible institution and the sanctioning mechanisms required when water is not released should be clarified.

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