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Environmental Impacts of Dams Around the World

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Abstract: A review of scientific literature, specifically in English, was carried out to identify the main impacts generated by the construction of large dams in Europe, Asia, Africa, Oceania and the Americas. In addition, a comparison was made between the impacts found in ex-ante studies and those found in ex-post investigations and significant differences were detected between the impacts identified in the studies before and after the construction of the projects. Thus, the interest in ecological and socioeconomic impacts, especially negative ones, predominates in the two types of studies, in contrast to the small number of investigations where the benefits of dams are evident. Finally, there are common impacts seen in almost all hydroelectric projects around the world such as the loss of economic sustenance, fertile land, jobs and physical displacement of people, among others.

Key words: Impacts, dams, ex-ante and ex-post environmental impact studies, sustenance, benefits

INTRODUCTION

Dams are built to produce positive benefits or impacts but even so, there are always unfavorable consequences or negative impacts that need to be prevented, mitigated, corrected or compensated significantly. This must be done in accordance with the legislation that in many countries regulates the conduct of environmental impact studies prior to the construction phase which are known as ex-ante studies. Nevertheless, there are also some cases of environmental impact studies that have been carried out after the construction phase which are known as ex-post studies.

The objective of this study is to identify in a simplified way the most frequent and important environmental impacts of large dams in the world and to establish the fundamental similarities and differences of such impacts recognized in ex-ante and ex-post studies.

To achieve this objective, a search and consultation of publications, mainly in English, on environmental impact studies of large dams in Asia, America, Europe, Africa and Oceania were carried out.

The results and conclusions presented in this article will be of interest to researchers, environmental analysts, teachers and university students who study the environmental impacts generated by hydraulic projects that include the construction of dams. It is also a document that can help the owners and builders of such projects to implement them with more social and environmental responsibility and on the other hand, can provide officials of environmental authorities with more knowledge to improve legal requirements processes of environmental licenses for these projects.

DAMS AROUND THE WORLD

Dams are built either to supply water for human consumption, to supply water to irrigation systems, to generate power or to control flooding; however, they can be multipurpose when two or more of these objectives are combined (Sternberg, 2006).

Small dams for potable water, irrigation or flood control have been under construction for several centuries. Reservoirs to produce hydroelectricity, on the other hand, began in the late 19th century in Western Europe and the United States and became established in the second half of the 20th century, according to Anonymous (2013) and World Bank (2009, 2013). This was due to the demand experienced particularly by emerging countries as a result of demographic expansion and relocation of large factories and industries in their territories.

According to the World Commission on Dams-WCD (2000), large dams are those whose main dam wall is equal to or >15 m in height or, failing this, a reservoir with a capacity to store more than 3 million cubic meters of water. The medium-sized dams have a main dam wall with a height ranging from 10-15 m and a reservoir with a capacity to store <3 million cubic meters. Finally, the small dams have a main dam wall with a height of <10 m and a reservoir with capacity to store <1 million cubic meters.

The first wave of construction of large dams originated from 1960 on the Mekong River in China (Anonymous, 2013). A second stage took place in 2000 in Brazil, when the government developed an ambitious hydroelectric plan on the Amazon River between 2012

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and 2020 (Fearnside, 2014). And larger dam projects are planned for the Congo and Zambezi rivers in Africa (Anonymous, 2013).

In general, the world went from having 9,056 large dams in 1960 to accounting for more than 32,500 in 2010 (World Bank, 2013). However, other sources assert that during the 20th century more than 47,000 large dams and 800,000 small dams were built around the planet (Richter and Thomas, 2007; WCD, 2000), highlighting Asia as the continent with the most dams (World Bank, 2013), especially due to China’s hydroelectric development (Miao *et al*., 2015).

Asia: According to Xu *et al*. (2013), the Three Gorges hydroelectric project on the Yangtze River in China began construction in 1993 and ended in 2009. Hence, the official report by which potential environmental impacts were estimated dates back to the early 1990s. These same authors state that a study was conducted with the objective of comparing the estimates included in this report with the results obtained in further investigations (Stone, 2008, 2011; Wu *et al*., 2013).

Xu *et al*. (2013) emphasized the most problematic aspects of the project such as water quality (Bi *et al*., 2010), fishery resources (Gao *et al*., 2010), sedimentation and erosion on the riverbank downstream (Lu *et al*., 2011), seismicity and geological instability caused by the reservoir (Wang *et al*., 2004), human displacement and the carrying capacity of the environment in the reservoir area (Xu *et al*., 2013).

Xu *et al*. (2013) found that: the displaced population increased by about 190,000 compared with the results of the official environmental impact study, Sedimentation was 142 million tons, 40% of the estimated 335 million in the same study and the inventory of specimens of the four species of trout of greater presence was reduced by 78%, compared to 50% estimated in the official report.

Likewise, in Iran, several authors carried out ex-post investigations on the economic, social and environmental consequences that the constructions of the reservoirs had on the areas of influence. In this regard, Khoshraftar-Moghadam (2009) analyzed the economic effects of the Tabarak and Ghochan reservoir on populations located downstream, finding a boost in agricultural activities, crop diversity and employment generation in the area. On the other hand, Rahmati and Nazarian (2010) found negative economic, social and environmental impacts as a result of the construction of the Gotvand Olia and Karoon dams on the populations upstream of the reservoirs. Similar economic results were found by Saedi (2012) which were caused by the Taleghan dam in terms of land use, land prices, rural livelihoods and availability of employment opportunities. In the same vein, Afshari and Ebrahimi (2013) showed how the area under cultivation increased, farmer’s incomes improved and the value of land downstream was increased as a result of the Hana dam.

Tilt *et al*.(2009) studied the impacts of large projects such as the Lesotho Highlands dam complex with five dams (three completed and two under construction) between South Africa and Lesotho. The Lesotho complex had the Katse, Muela and Mohale dams fully completed, while the Mashai and Tsoelike dams were still in the planning phase by the end of the 2000s. The Highlands project has among its objectives the provision of water for the industrial region of South Africa and the generation of electrical energy at national level. The completed dams are located in one of Lesotho's poorest and most remote areas, with high levels of unemployment and poverty.

Tilt *et al*. (2009) classified the impacts in three categories, namely: Impacts on the rural economy; on culture, health and gender and on infrastructure, transportation and housing. In the first category, the loss of access to land and other resources such as drinking water sources, natural springs, herbs and vegetables, all necessary for the well-being of communities, prevailed. In the field of employment, there was a high level of migration from the lowlands to the Lesotho highlands and thus a pressure on the employment possibilities of the localities. In the second category, there were about 20,500 residents affected in 120 villages. Regarding the third category, women were the most vulnerable and negatively affected.

Siciliano *et al*. (2015) studied the post-construction effects of the Kamchay Reservoir (Cambodia) in 2006, based on the perceptions of affected community members and institutional actors at both local and national level. In addition, the investigation determined the distribution of impacts between national, local, rural and urban areas. Among the most significant environmental impacts were the low water quality of the Kamchay River which supplies the city of Kampot; the salinization of water due to the proximity of the reservoir to the sea and the dramatic deterioration of biodiversity. At a social level, serious affectations were found in four interest groups: bamboo collectors, firewood collectors, fruit sellers and durian fruit producers, but no resettlement processes were required because although the reservoir flooded more than 2,990 ha, including roads and basic infrastructure of the region, it was built on the land of a national park.

Among the bamboo collectors, before the dam, 47% of families earned more than 20,000 Riels and 53% <20,000 Riels per day, while after construction 21% gained more than 20,000 Riels and 79% earned <20,000 Riels per day which shows a deterioration in their economic situation. Similarly, families dedicated to the collection of firewood increased from 20 to more than 50 after construction and fruit producers went from 19% of the population to 2.5% with a population with incomes >30,000 which decreased from 86-23%. Likewise, the influx of tourists decreased from 280,000-65,000 people per year (Siciliano *et al*., 2015).

Africa: Africa is one of the continents where the largest numbers of dams are intended for crop irrigation and to a lesser extent for hydroelectric generation. Ahmed and Fogg (2014) evidenced the impact generated by the increase of groundwater levels as a result of the construction of the Aswan Dam, causing the deterioration of archaeological sites due to its humidity and salinization.

In Kenya, Rempel *et al*. (2005) examined the effects of small dams on surrounding populations, with improvements in agricultural productivity, the main livelihood activity in the region. Likewise, they showed savings in irrigation time, biodiversification and the appearance of new crops.

Pauw *et al*. (2008) studied the consequences of small dams in Sant River in Kenya and found major negative impacts on farmland, agricultural production and farmers' incomes. On the other hand, the investigation revealed that the incomes from non-agricultural activities increased for people who had access to the dam’s water, in relation to inhabitants who did not.

Similarly, Khlifi *et al*. (2010) demonstrated the positive impact of small dams on the economy and well being of communities in the Jendouba region, northeast of Tunisia. Among the main benefits were the significant increase in irrigated areas, the expansion of cereal crops and foraging vegetables in the summer. In the same way, the cultivation of fruit trees increased and the farmers changed their bovine races to more specialized specimens in milk production as a result of the availability of fodder all year round which brought with it a significant increase in the farmers’ incomes.

Strobl and Strobl (2011) conducted an extensive study on the impacts of large dams on the African continent. They used the FAO classification for large dams (those that were at least 15 m high and/or a storage capacity of at least three million cubic meters of water) accounting for a total of 972 dams for analysis. The study showed that 65% of the dams were irrigated, while 13% and 38% provided drinking water and electric power respectively. Finally, they concluded that the regions that were widely benefited by the increase of the productivity of their crops are downstream of the dams. However, the research did not address important issues such as population displacement, impact on fisheries and erosion on the river basin, among other negative consequences.

Mudzengi (2012) analyzed the effects of the construction of the Siya Dam in Mazungunye, Zimbabwe and discovered that farmers achieved better agricultural production, despite poor and adverse environmental conditions. Fishing activity was another one of the beneficiaries of the construction of the reservoir, with the growth of capture fisheries by the inhabitants which benefited the subsistence of the population of the area of influence.

Muwumuza (2014) developed an investigation into the impacts of the Bujagali hydroelectric dam in Uganda. In this regard, it found negative impacts on 634 displaced people because they lived in the floodable area. Nevertheless, the neighboring communities were compensated with the construction of drinking water aqueducts and a power supply system for their homes, as well as schools and health center. Among the most conflicting aspects of the construction of the reservoir was the cultural factor as a consequence of the organization in tribes, who considered that they would lose customs and that ancestral spirits would be disturbed with the resettlement, a situation that was ultimately compensated in money.

Obour *et al*. (2016) discussed the impact of the Bui hydroelectric dam on livelihoods of local communities in the Republic of Ghana. Before the dam, the main economic activities were fishing and agriculture and a complex system of commercial exchange between its inhabitants. However, the fishermen experienced a notable decline in the number of fish available due to the interruption of breeding cycles and changes in river flow regimes, as well as problems in accessing fishing sites. The resettled people were located several kilometers downstream which hindered fishing activity because river flows declined dramatically. The issue was complicated by the practices of the Bui Energy Authority, opening dumps without warning and increasing water flow which often led to the loss of fishing nets and canoes. Also, it was found that the construction of the dam allowed the appearance of several formal jobs in the area; nonetheless, the vacancies were covered by outsiders, due to the low level of qualification of the inhabitants. In summary, only 14 of the 139 people eligible for construction work in the area were employed and the rest were migrants.

Alrajoula *et al*. (2016) found that the Er Roseires dam in Sudan, after 50 years of operation on the Nile River, generated serious environmental and social impacts. On the one hand, it caused recurrent environmental problems at the low levels of the river, especially in the dry season, as well as the displacement of about 110,000 people. In the same vein, the increase of humidity in the area increased respiratory problems in its inhabitants. On the other hand, it generated positive impacts on the economy of surrounding communities, with increased fishing and marketing, agriculture and tourism, as well as providing wood and fruit, especially of aquatic origin.

America: In the United States, dam construction is a twentieth-century affair. However, it is estimated that there are around 75,000 dams between small, medium and large (Bohlen and Lewis, 2009). Despite the benefits generated by such projects, the negative impacts are evident. In the State of Maine, hydroelectric projects have greatly affected the Maine River, causing deterioration of aquatic habitats and survival of the threatened Atlantic Salmon (Lichter *et al*., 2006).

Douglas and Harpman (1995), using the Impact Planning and Analysis Model (IMPLAN), estimated the value of income generated by recreational and sporting activities in the Glen Canyon reservoir area. Based on tourist expenditure and the income received by the local economy, they estimated the number of jobs generated for the study area. The income earned in the area by tourist activities was calculated at USD 11.66. 813 in 1985 and USD 14,167,847 in 1990 and, consequently, the employment estimate for the two periods was 316 and 307 jobs, respectively.

Bohlen and Lewis (2009) conducted a study to determine the impact of dam construction on the value of property in the State of Maine, using a statistical model of information analysis, finding a correlation with negative impacts such as deforestation, bad odors, deterioration of water quality, reduction of fish and loss of value of properties around reservoirs.

Austin and Drye (2011) also studied the impacts of the Glen Canyon Dam on the Colorado River in Northern Arizona. In this regard, it was documented how the local and national governments weighed up the alternatives, having to choose between the income generated by tourism and recreational fishing on the one hand and food security on the other. The study evidences the impacts on native animal and plant species that were faced with extinction, as well as on tribes of indigenous people who saw their food sources altered. Nonetheless, the study showed the benefits for tourist activity in the region with millions of dollars in revenue.

In another case, Keilty *et al*. (2016) reviewed the impacts caused by the Mactaquac dam in Canada before and after construction. In the pre-construction stage, negative perceptions of the loss of land for agriculture, the resettlement of some people and the diseases as a result of the stress and worries generated were outstanding. After the realization of the project, the inhabitants identified positive consequences in the community, such as the possibility of nautical, sports and tourist activities, due to the attractiveness of the coasts and beaches that appeared with the reservoir.

In the Central American region, specifically in Honduras, Lehmann (2001) conducted an analysis of the Francisco Morazán reservoir, better known as El Cajón, built between 1980 and 1985 by a consortium composed mainly of European companies. The reservoir was built on the Comayagua River, remarkable for its fishing resource in the central region of the country and generated positive and negative consequences on the area of influence, in particular minimising the floods caused by recurrent hurricanes and tropical storms affecting Central America.

According to Loker (2003), before the construction of the El Cajón dam, its area of influence had a total of 9241 hectares (Ha) of land for agricultural use, but the filling of the reservoir flooded approximately 3577 ha and agricultural lands were reduced to 5664 ha. However, in 1994 (approximately 10 years later), 8965 ha were reported, almost the same agricultural area as before the dam that is the agricultural frontier was expanded but at the cost of forest loss. The nature of the region's productivity changed due to the increase in cattle rancher's economic capacity (as a result of the compensations received) which resulted in them buying a large part of the available lands or extending their farms to the detriment of the forested areas. This generated problem of access to land for agriculture. The reduction in the sources of resources for subsistence for the community made migration to the United States an alternative at least 50% of the families living in the area had a relative in North America from whom they received economic support.

In Guatemala, Aguiree (2005) found negative effects such as the decline in agricultural and livestock activity and the gradual loss of jobs, following the construction of the Chixoy Dam between 1976 and 1985. Furthermore, according to ODHA (1998) and CEH (1999), the multiple affectations, the discontent of the communities and their refusal to leave the land to give way to the Chixoy reservoir, resulted in the massacre of Rio Negro (440 people) executed by the Guatemalan army over the civilian population.

Aguilar-Stoen and Hirsch (2015) examined how environmental impact studies, despite being conceived as neutral instruments for assessing possible social and environmental impacts and helping decision-making, became merely a bureaucratic process, in which projections of negative impacts tend to be underestimated, even with the complicity of the authorities responsible for reviewing and endorsing the issuance of permits and licenses.

In South America, Goodwin *et al*. (2006) paid particular attention to the consequences of hydroelectric dams in Chile, where they reported losses in river biodiversity, the appearance of aquatic vegetation, loss of river longitudinal connectivity and a high mortality rate in aquatic organisms. Additionally, some phenomena were found, including the decrease of native species and the proliferation of exotic species, decrease of the quality of the waters downstream of the dam, loss of migration corridors, even with the change of the salmon migration patterns from the pacific and other salmonids.

Magalhaes *et al*. (2009) later analyzed the environmental impact study, to determine its failures and the social, economic and cultural situation of the area affected by the construction of the Belo Monte dam in Brazil. Among the shortcomings of this study are the underestimation of the resident rural population and distortion of the data of the elementary characterization of the population. Normal migratory flows in the Xingu and Altamira region were not taken into account in the population projection, being limited only to the migratory impact of the project. There is also criticism about shortcomings in estimating the specific production and trade flows of agroforestry systems that traditionally support the domestic market and trade with the foreign market. In summary, the researchers considered that the environmental impact study carried out superfluous calculations on the economic dynamics of the region.

Flores-Vichi (2002) evaluated the economic impacts derived from the construction of the El Abrevadero dam for irrigation purposes, located in the municipality of Jantetelco in the state of Morelos, Mexico. The irrigation system allowed the production and income of several crops to increase. For example, the economic income of the sorghum plant saw an increase of 40%, while that of rice and onion plants increased by 30%. However, it is considered that the volumes of water used are exorbitant compared to the yield and income obtained, due largely to the lack of rationality in the use of water resources as a consequence of their low cost.

Tagliaferro *et al*. (2013) analyzed the possible effects of the construction of two hydroelectric dams on the Santa Cruz River in Argentina and five on the Baker and Pascua rivers in Chile, located in Patagonia. The loss of a rich variety of macroinvertebrates stands out, estimating that a little more than 50% of the lotic ecosystems of the aforementioned rivers will be lost.

Fearnside (2014) highlights the problems and lessons left by the construction of the San Antonio and Jirau dams over the Madeira River in the Brazilian Amazon, on the border with Bolivia and Peru. The loss of the fishing resource is one of the greatest impacts on the community, especially the large migratory catfish group known as the "big catfish" and its five species of commercial interest. Before the dam, these species went up to the head of the tributaries of Madeira to breed. Although, the environmental impact study proposes a fish transposition infrastructure, scientifically untested, this serves for the adult fish to come to spawn but does not work so that the larvae descend to feed on the lower part of the river which is why the presence of fish along the Madeira and its tributaries has been drastically reduced. On the other hand, replacement activities to provide employment, such as the construction of an artificial beach and a tourism center in the old Teotonio waterfalls, appear to be insufficient to provide a viable livelihood for the population due to the unsanitary conditions of the water of the dams.

Aledo *et al*. (2015) presented the results of ex-post assessments for the Porto Primavera and Rosana dams, in the upper Parana River in Brazil, on the population of Puerto Rico. There was a change of productive vocation and the community went from having fishing tourism, to beach and sun tourism. In effect, it moved from the primary sector to the tertiary sector of the economy. Nonetheless, the negative effects on river flow and wildlife were noticeable. High mortality of fish as a result of the pollution generated by tourism, wastewater discharges on the reservoir, low water levels and pollutants used to clean the turbines are the most highlighted negative effects. Although, the occurrence of aquatic weeds was identified, they encouraged the survival of the fish but hampered the navigation of fishing vessels.

In the same vein, Fearnside (2016) carried out another analysis of the impacts generated by the Itaipú dam on the Brazilian Amazon. Among the aspects that he found are the consequences on the populations located downstream of the dam, because a stretch of about 100 km was altered in its course, leaving it totally dry when it had been historically used for irrigation and fishing. The migrations of fish, downstream and upstream, were interrupted by the reservoir, putting at risk the self-sufficiency of the region which largely supported its economy through fishing.

In Colombia, environmental impact studies have been carried out in order to process environmental licenses for the construction of several hydroelectric power stations and irrigation and drainage projects, mainly since the early 1970s. Although few in number, some ex post studies have also been carried out in order to monitor the adverse and favorable impacts of the hydroelectric projects in operation as happened with the hydroelectric plants of Urrá I, Urrá II and Betania.

Alzate *et al*. (1987) established the social impacts generated by the construction of the Urrá I and II hydroelectric plants, especially the drawbacks related to the displacement and resettlement process of two indigenous communities in Alto Sinú, as well as several communities of settlers. A population increase was also noted in the municipality of Tierralta as a consequence of migration that occurred as a result of the works carried out which in turn resulted in speculation of the price of urban land and consumer goods. In addition, the loss of 60,200 ha of land suitable for agriculture generated an avalanche of settlers in search of new lands to develop agriculture, in other words, it stimulated the expansion of the agricultural frontier.

The reservoir of the Betania Hydroelectric Power Plant Colombia (BHPPC) is located on the Magdalena and Yaguará rivers in the department of Huila. Hydraulic works and the filling of the reservoir ended in 1986 and 1987, respectively. The Universidad Nacional de Colombia (1985) carried out an environmental impact study when BHPPC was still under construction and between 1990 and 1991, Olaya *et al*. (1992) from Universidad Surcolombiana carried out a study with an emphasis on social and economic effects of the same power plant. Although there are differences in the type and assessment of impacts, in both cases, impacts related to the reduction of the agricultural and livestock area and agricultural unemployment are recognized. Some impacts identified were: the interruption of migration and the decline of native fish but with an increase in the fishing resource of other species, deterioration of water quality, increased tourism and recreational potential, favorable and adverse changes in road infrastructure and transportation, displacement of agricultural workers and an increase in urban population.

The El Quimbo hydroelectric project, also built on the Magdalena River in the department of Huila, obtained an environmental license through Resolution 0899 of 2009 (Anonymous, 2009) and entered into operation at the end of 2015. According to the same resolution the most important impacts (among others) are related to the loss of forest cover, effects of both terrestrial wildlife and hydrobiological resources, modification of aquatic and terrestrial habitats, deterioration of water quality, disappearance of 8,586 ha, affecting employment and productive activities, loss of connectivity between human settlements, cultural heritage and archaeological heritage, migratory pressure on urban centers and modification of the municipal territorial order.

Europe: Batalla *et al*. (2004) analyzed the levels of flows in the Ebro river basin (Spain) and found that the 187 dams that regulated it affected drastically its annual mean, although, the frequency of floods decreased dramatically downstream.

According to Bettencourt and Grade (2009), the Alqueva multipurpose project, completed in 2002, is located on the Guardiana River between Portugal and Spain. With 120.00 ha for irrigation and an installed capacity of 380 MW, it is the largest dam in Western Europe with more than 25,000 ha and an irrigation district which can reach around 120,000 ha. Santos *et al*. (2008) carried out an ex-ante and ex-post comparative study of the impacts generated by the Alqueva dam on threatened carnivorous animals in the area of influence which acknowledges that despite the benefits provided by irrigation, there are serious negative effects on animal species such as the otter, the Iberian lynx, the wild cat and the skunk. Nevertheless, programs for the conservation and repopulation of endangered species are being developed. Dias-Sardinha and Ross (2015) studied the impact of the dam on the tourism industry and demonstrated that, against initial expectations, this industry is largely underdeveloped partly due to a lack of investment and inadequate planning.

Loizeau *et al*. (2010) took into account the impacts generated by 160 large dams in Switzerland, including Mauvoisin, Wettingen and Grande Dixence, three of the most important in the country. They emphasized changes in frequency and reduction of annual water discharge downstream, reduction in sediment and nutrient load, as well as a reduction in the frequency and the extent of flooding.

Carracedo Martin and Garcia Codron (2011) studied the impacts of the four dams for electricity generation that are located along 40 kilometers of the Nansa river in Cantabria, Spain. Such dams severely affected the life cycles of animals moving between the river and the sea, especially, fish such as salmon, trout, eel and lamprey. The first three were heavily exploited during the first decade of the twentieth century and by 2011, almost extinct. Aquatic mammals such as otters and Iberian desman are also strongly affected by the barrier effect of dams which are found in some of the upper stretches of the river basin. In addition, the Nansa river became a small stream with the aggravating factor that significant changes were detected in the parameters of pH, temperature, dissolved oxygen, suspended solids and nutrient load attributable to the dam effect and/or decrease of the discharge flow and the loss of self-purification capacity.

Oceania: In Australia, Walker (2008) examined the potential impacts of the Traveston Crossing dam on the Mary river, a highly sensitive ecosystem due to the country's iconic species such as turtle, cod and Australian lungfish. An ex-post analysis was made based on the environmental impact study presented by the Australian environmental authority and there is a high probability of increase in water temperature and nutrient enrichment that will generate the appearance of significant algae and herbs with high levels of eutrophication, affecting the quality of the water resource with implications on the flora and fauna of both the reservoir and the river. As a result, water with low levels of oxygen, heavy metals and sulfur compounds are likely to occur, potentially impeding the development of fish and other animals as well as the risk of using water for human consumption.

At a general level, with the analysis of several reservoirs located in America and other continents, Ledec and Quintero (2003) conducted a study for the world bank which found that hydroelectric projects generate a series of impacts on their environment. Among the most relevant are: flooding of natural habitats, loss of wildlife, forced displacement of people, deterioration of water quality, hydrological changes of the river downstream, occurrence of water-related diseases, changes in aquatic animal life forms, emergence of aquatic weeds, loss of cultural and immaterial heritages, generation of greenhouse gases and sedimentation of reservoirs.

Ledec and Quintero (2003) attribute most of these impacts to an incorrect selection of the reservoir site. For this, the authors use as examples the cases of small or medium reservoirs that have a great capacity to generate electrical energy and in turn, have caused very little physical displacement of people. These reservoirs are generally located in the upper reaches of the rivers, with little presence of human settlements but with a large number of wild habitats. Technically, reservoirs are smaller in extent but compensate in depth, giving them more capacity to generate power.

Other researchers consider that the great tensions generated by the construction of large infrastructure projects and especially dams are due to the fact that local impacts are not usually taken into account, especially, negative impacts on the environment and communities (Ansar *et al*., 2014; Pearse-Smith, 2014).

In the same vein, Fearnside (2014) states that many of the impacts fall on local populations living along rivers that are or will be dammed, while profits accumulate in distant cities, even in other countries. In addition, the World Commission on Dams (2000) considers that the most significant impacts are the displacement of communities and that the construction of dams has generated the physical displacement of approximately 40-80 million people, with the adverse consequences of the respective Resettlement processes.

CONCLUSION

Dams generate favorable and adverse consequences. However, ex-ante and ex-post studies highlight, in particular, negative impacts. Ex-ante studies are more frequent and are carried out to process the environmental license of the projects, while ex-post are scarce, their interest is more recent and they are made for the purpose of tracking impacts, detecting which of these are underestimated or overestimated and finding out about new impacts. Thus, measures of the environmental management plan of the project, territorial reorganization or socioeconomic development of the respective area of influence can be better reoriented. Therefore, it is advisable to consider the mandatory nature of environmental impact studies after the construction of dams.

In both types of studies, interest in negative ecological and socioeconomic impacts predominates, but the limited amount of research on cultural and ethnographic impacts on affected populations is noteworthy. Among the main adverse consequences recognized in such studies carried out around the world are the physical displacement of people, resettlement processes, loss of sources of employment and economic sustenance; the interruption of migratory corridors of animal species, mainly aquatic; the loss of habitat and the extinction of animal and plant species. This trend may be due to the fact that environmental licensing legislation tends to emphasize unfavorable impacts much more. However, it is also recommended that a leading role be given to the positive impacts, because this would facilitate better planning of local or regional development, taking advantage of the new opportunities associated with the construction and operation of dams.

In other words, the main impacts of dams, both positive and negative, are common in the vast majority of regions around the world. However, their assessment varies perhaps according to the particularities of each country which seems to be explained by economic, legal, cultural and social variables, social sensitivity and resistance, as well as the professional ethics of consultants and officials, the number of inhabitants and the type of ecosystem affected.

In most of the studies examined, with negative consequences such as those aforementioned, the most affected are low-income communities, including indigenous settlements, engaged in economic activities with no or little use of technology and capital. They are usually people engaged in crafts and low-skilled trades such as fishing, logging, subsistence farming, hunting or day laboring, among others, who would be inserted into new models of economic sustenance with much difficulty, despite compensation, because they do not possess the necessary knowledge or skills to perform in new occupations.

For their part, those devoted to economic activities, with certain capital requirements and use of technology, have developed relative knowledge and skills that allow them to adapt more easily to the new challenges posed by the construction of dams, as happens with medium and large cattle growers, traders, small agro-industrial or tourist companies, landowners, medium and large-scale farmers.

However, there are a small number of investigations where the benefits of dams are evident. For example, in Africa, studies have focused on highlighting the economic benefits experienced by surrounding populations who enjoy an irrigation system for their crops with water supplied from built dams with advantages such as significant increase in both cultivated areas and agricultural production, crop yields per unit area, frequency of crops and agricultural diversification.

In accordance with the above, it is appropriate to state that, although, hydraulic projects generate significant economic benefits for the owners or the development of the country, the communities in the immediate area of influence tend to look sympathetically at those who improve their income and employment, without causing them to be displaced or dispossessed of their land or housing. This is achieved through irrigation dams, multipurpose projects that include land suitable for agricultural purposes or dams with different objectives than hydroelectric generation. As a hypothesis, it could be expressed that the community and institutional inhabitants and actors in the project’s area of influence tend to tolerate adverse ecological impacts when they generate significant favorable impacts of socio-economic interest in that area, in addition to the compensations.

In this respect, it can be added that some researchers consider the economic compensations, given to affected people by project owners as part of the benefits generated by dams. The latter situation should only be interpreted as compensation for the loss of environmental, social and economic assets that the communities had before the beginning of the projects and which were lost or damaged as a direct consequence of the projects.

For all of the above, the authors consider it viable and necessary to build a master list of verification of ecological, economic and social impacts of dams, to facilitate methodologically the identification and selection of these impacts of any given hydraulic project with a reservoir in any country in the world.

Finally, there are environmental impact studies or equivalent dam investigations from the end of the last century which are very valuable for carrying out comparative analyzes over time but have not been published in magazines. Thus, in case of research studies with historical purposes about a particular dam, it may be necessary to consult the libraries of institutions that represent the relevant country's environmental authority, or universities with academic programs related to the use of water resources, generation of hydroelectricity or adaptation of land for agricultural purposes.

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