



External Interventions and Community Innovativeness to Cope with Changes in Ecosystem Services of the Okpara Dam in Northern Benin

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Authors' contributions

This work was carried out in collaboration between both authors. Author SB designed the study, wrote the protocol, collected the data, performed the analysis, and wrote the first draft of the manuscript. Author LI contributed to design the framework of this study. Both authors read and approved the final manuscript.

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ABSTRACT

The Okpara dam in Northern Benin offers multiple ecosystem services (ESS) to the riparian communities living around. It is an important drinking water source for the populations of the largest nearby metropolis Parakou. Many development activities have been undertaken to increase its capacity to supply drinking water by the Benin national water Company (SONEB: Société National des Eaux du Bénin). These activities combined with climate change are drastically affecting the sustainability of ESS supply. This paper aims to analyse the determinants of changes in the provision of ESS and to assess the local innovations developed by local communities to adapt to these changes. Data collection consisted in interviewing 111 individuals in the nearby villages of the Okpara dam. It included farmers, fishermen, religious dignitaries, SONEB officials, and traditional leaders. The results show that the modernization work undertaken by SONEB has increased the capacity of the dam to supply drinking water to the Parakou's population. On the other hand, they have deprived the local communities of many ESS such as cultural and religious spaces, entertainment and agricultural production areas. In addition to these development works, climate change and other anthropic actions are also cited as factors explaining the depletion of

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certain ESS around the dam. To limit the damage and safeguard agricultural production, local population have developed agricultural areas downstream of the dam with the creation of autonomous water points for market gardening. Fish farming areas have also been created for small-scale fishing. These innovations have helped not only to improve the availability of drinking water but also increase the income of farmers and fishermen and improve the social cohesion among the communities.

Keywords: External interventions; ecosystem services; innovativeness; water resources management; North-Benin.

1. INTRODUCTION

Ecosystem services (ESS) are provided by a large number of physical and ecological functions [1], ecosystem services do not only depend on the interactions between soil and atmosphere, soil and vegetation cover, biodiversity and its interactions with other components of the environment but also on the conditions of land use and occupation or climatic dynamics. This multifunctional system shows the needs, desires, competing practices, uses and representations [2].

Despite the fact that water is considered as an indispensable element, both for humans and the rest of the living species, the current state of the earth's drinking water sources has to be questioned. Water sources and aquatic environments are constantly disturbed by human activities [3,4]. These disruptions take well-known forms such as various chemical pollutions and those due to waste discharged directly into rivers or water bodies [5]. In addition, there are other problems that are less mentioned, such as thermal pollution and ecosystem disruption of rivers due to construction and dams, whose impact is by no means negligible [5]. Moreover, forecasts predicted a decline in per capita water availability in the coming decades [6].

Furthermore, under the pressure of population growth combined with increasing impoverishment, protected areas are highly affected. So, the population growth is forcing farmers to seek new agricultural land no matter the consequence on the environment. [7,8]. Consequently, the balance of the ecosystem of water bodies and rivers and the health of population around is affected [5].

On the other hand, Africa is particularly affected by climate change and becomes very vulnerable [9]. Many scholars also demonstrated that climate change could worsen the pressure on water resources and food security [10,11,12]. The situation requires adequate strategies in

managing water resources [13]. Studies carried out on these aspects showed the importance of taking into account external and internal actors in the governance of water and climate change [14].

The case of the Okpara dam is a perfect illustration of how external interventions can positively or negatively affect the ecosystem services generated by a water resource. Indeed, this dam, which is an important source used by the Benin national water Company (SONEB) to supply the populations of the city of Parakou with drinking water, has undergone major development work that has increased its capacity to produce and distribute drinking water, which at one time of year was becoming a rare commodity. It is essential to investigate the dynamics imposed by these interventions coupled with the effects of climate change on the various ecosystem services generated around this resource and to determine the socio-economic implications on the human communities living around.

This research aims to i) understand the dynamics of ecosystem services following the development work undertaken at the dam; ii) analyze the explanatory factors of these dynamics and iii) analyze the innovativeness of the various actors (institutional and human populations) to adapt to these dynamics of ecosystem services.

2. THEORETICAL AND ANALYTICAL FRAMEWORK: FROM SOCIAL REPRESENTATION THEORY TO ANTHROPO- ECOLOGY

According to the theory of social representations [15], knowledge emerges from common thought, which is shaped during interactions where the processes of transmission and construction are intertwined [16,17]. In this theory, a central role is given to the social as a place of co-construction and sharing of knowledge between individuals [18]. Social representations are conceived as dynamic sets that make possible to interpret and

intervene on reality [15]. They are formed through relationship between individuals. They are whether convergent, or conflicting [16]. Indeed, several socio-economic factors such as age, gender and migration influence the knowledge of ecosystem services related to water resources [19,20,21]. Furthermore, where the relationship between humans and their natures will preoccupy the ethnologist, the ecologist will focus on the relationship between nature and their societies, thus reversing the order of epistemological priorities. The anthropo-ecologist, on the other hand, will be in search of the anthropological and ecological invariants of the dialectical relationship maintained by man and nature [22]. The combination of these two theories is interesting in order to better understand the link between populations and their physical, social, economic and political environments. It helped us understand possible interactions in order to effectively address the effects of changes in ecosystem services on the nearby communities of Okpara dam [23,24,25].

3. METHODOLOGY

The study was conducted in the district of Tchaourou and the municipality of Parakou in northern Benin, in the department of Borgou. They are located at 8° 52' 60" North latitude and 2° 36' 0" East longitude. Okpara is a river that has its source in Darou Kparou, a village of

Pèrèrè district. It is a tributary of the Ouémé River, with an irregular flow varying between 0.0001 and 150 m³/s. It is about 362 km long and has a total area of 10,000 km² [26]. Its watershed has a surface area of 2,070 km² and largely covers the districts of Bembèrèkè in the North, Parakou and Tchaourou in the South, Pèrèrè in the East and N'Dali in the West of Benin. Three villages bordering the Okpara dam were researched, namely Kpassa, Kika and Kassouala (Fig. 1). Quantitative and qualitative data were collected from 111 individuals randomly selected, including 37 women and 74 men from different socio-professional groups: 49 farmers, 12 herders, 30 fishermen, 15 religious and traditional leaders and 5 leaders from the Benin national water Company (SONEB). The data collected relate to their socio-demographic characteristics, their socio-economic activities, their perceptions of the ecosystem services provided, the changes observed in the provision of ecosystem services, and innovative local and institutional measures for adaptation to the dynamics of ecosystem services [27,28].

The qualitative analysis methods used consists in examining various dimensions of the discourse of the people interviewed. The relationship between discourse and context or syntactic structure was also examined as suggested by [29]. In terms of quantitative data analysis frequencies and means were calculated.

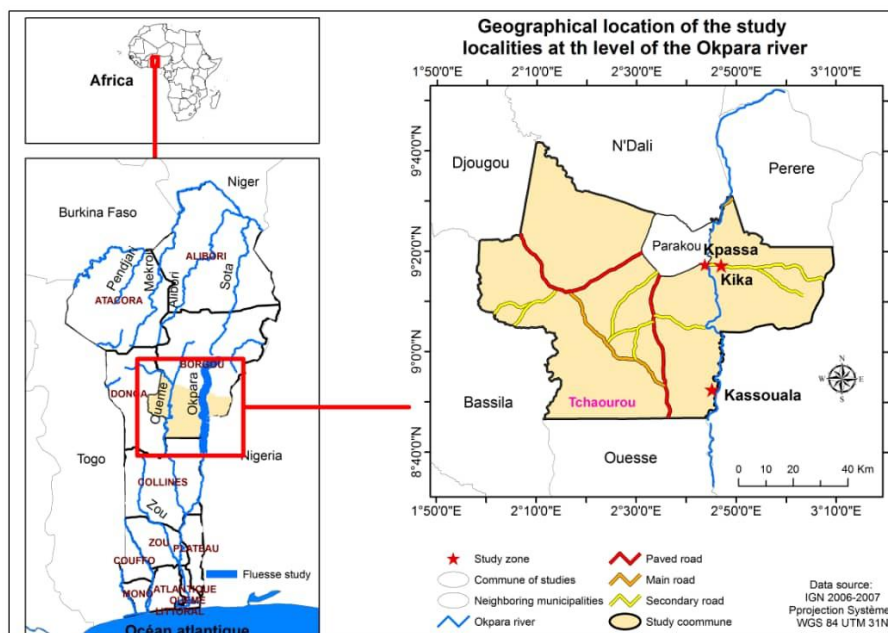


Fig. 1. Geographic location of the research area

4. RESULTS

4.1 Dynamics of Ecosystem Services generated around the Okpara Dam

Several ecosystem services are generated around the Okpara Dam ecosystem. Fig. 2 below shows the services identified according to their importance for the riparian communities.

4.1.1 Okpara dam as a recreational swimming place

The main ecosystem services offered by the dam and recognized by more than 93% of the respondents is its emblematic landscape that offers bathing and entertainment spaces to the riparian communities. In fact, this landscape represents for the human communities living around what the beach is for the populations located in the coastal areas. The place is a right place for youth even couples for picnic or entertainment. The nearby villagers take advantage of the place by taking bath after a long day of hard work in their farms when returning home. During the field survey, one respondent declares this:

"Every evening, we take advantage of this dam. When we return from the field, we take bath before going home. It is a strategy to limit the waste of water in the household especially in the dry season." Interview with T.R., Kika, 23/07/2020.

This testimony demonstrates the crucial role of the dam in helping the population to cope with water scarcity especially during dry season

4.1.2 Main source of drinking water for households and domestic use

The second main service mentioned by 78% of respondents is the supply in water. For more than forty years, the Okpara dam has been used to supply Parakou (Third biggest city of Benin) and surrounding areas with drinking water. In order to strengthen the function of the dam in the distribution of drinking water to the taps, massive investments have been made and structural reforms carried out by the Benin national water Company (SONEB) and the Government. It allowed to improve the quality of the service offered to the people who subscribe to the SONEB. It has solved the shortage of drinking water for the users.

Apart from drinking water, the dam provides the community with water for various domestic uses including washing, cooking, drinking and other economic activities. Indeed, several laundry camps are set up around the dam in order to punctually solve the problems of water deficit which arises especially during the dry season. From the analysis of the results of the data collected from the populations, more than 70% of the respondents acknowledge using water from the river for various needs. At the same time, they stated that they use an average of four to six basins or cans (25 liters) of water per day. One respondent told us:

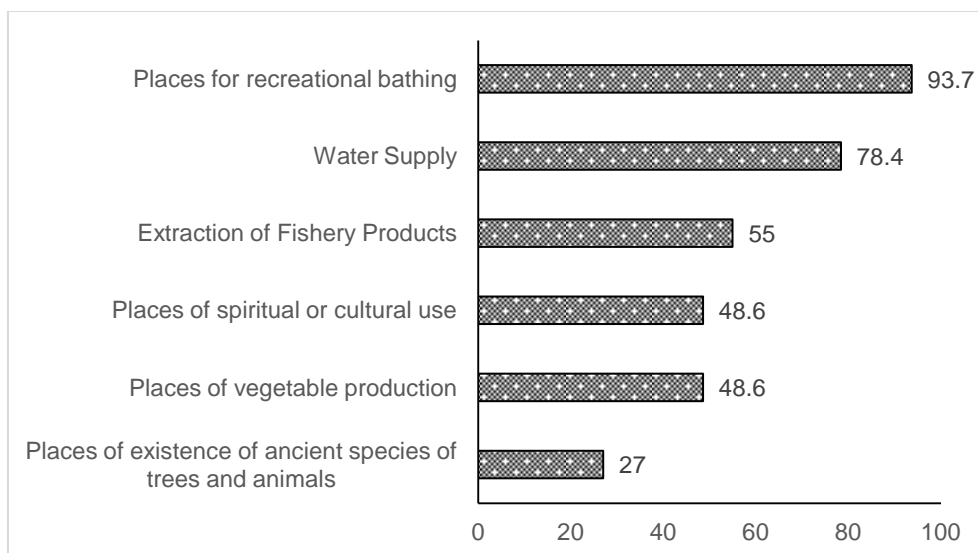


Fig. 2. Ecosystem services provided by Okpara dam (source: data collected, 2020)

"The existence of this resource relieves the pain of the people of our villages. We take at least four basins of water every day for our needs" said T.R., Kika village, 23/07/2020.

These words show how dependent the populations are on this resource and the need to preserve it against all possible destruction.

4.1.3 Place for fishing and agricultural production

Artisanal fishing is one of the activities developed in the Okpara dam ecosystem. It offers the local populations various fish products to meet their needs in animal protein. The market of Kpassa in Kika District offers a framework for the populations especially from Parakou who come there every morning to buy freshwater fish from women sellers or fishermen.

Seven out of the ten women fish sellers we met in the field said that they supply fish to restaurants and hotels in the city of Parakou every day. The others sell their goods to local communities or to other clients who come on a casual basis. A woman reseller we met in the village of Kpassa said:

"I have my customers who order in advance and are the first to be served when my husband arrives from fishing. The rest is sold to the first arrived among the other customers". (A. I, 22/07/2020).

Okpara Dam ecosystem offers a multitude of opportunities for agricultural development too. Different agricultural activities are carried out such as soybeans, maize, bananas production and market gardening. The crops produced particularly maize, millet and beans are the main staple food for a large proportion of the population. According to the information gathered from the interviewees, each household produces an average of 7 to 10 bags (100 kg per bag) of maize per year. At the same time, they stated that 75% of their production is intended for consumption and the rest is used to supply local markets and for seeds for the following season.

4.1.4 Place of worship and cultural uses

The ecosystem around the dam is used for cultural and religious purposes as well. There are endogenous practices which consist in venerating the divinity that resides in the watercourse upstream and downstream of the

dam. There are also external actors, notably religious believers (especially Islam and Christianity) who go to the place for prayers or exorcism sessions. Rituals of head washing, immersion or baptisms were often practiced there. Some objects and the remains of immolated animals are easily discernible on the site. These spaces offer emblematic landscapes that are conducive to communion with the spirits of the water and the forest, according to the testimony of some respondents. One respondent testified:

"We come here to get rid of our impurities and be born again. We have satisfaction when we come here to pray". (Z.A., Kika, 23/07/2020).

Another said:

"In the river, there is a great power that we have been worshipping for years. Every year, we make sacrifices to benefit from its protection and avoid cases of drowning of people". Reported T.R., Kika, 23/07/2020.

These testimonies show the degree of spiritual practices in this ecosystem and their importance in the eyes of the dignitaries and followers various religions encountered in the field.

4.1.5 Ecological reserve

According to people interviewed, the Okpara dam ecosystem is made up of forest where several species of plants and animals cohabit. These totemic animals often alert the populations of disasters or droughts that are coming to the village. As result, people prepare themselves to minimize the damage. People met in the research area confided that some of the tree species encountered are used in the pharmacopoeia to cure certain diseases and ward off bad luck.

As an illustration, one respondent said:

"With a little attention, we receive from nature (birds) signals of bad luck that are about to come in the village. Also, several cases of illnesses are cured with our plants without necessarily going to hospital". Said, G.P. in Kika, August 29, 2019.

According to most of the religious dignitaries we met in the community, the scarcity of certain medicinal plants and the disappearance of some totemic animals such as snakes, crocodiles, lizards are contributing to natural imbalance.

That affects people’s well-being. During the interviews, one of the respondents stated:

"Even some of our totemic animals namely, the monitor lizards, the herald birds, the giant termites, are gradually disappearing. Before, when a disaster was about to strike the village, they would appear to give the alert so that people could prepare for it. Nowadays, this is no longer the case." (G.P., Kika, August 29, 2019).

4.2 Changes in Ecosystem Services Provision and their Determinants

Fig. 3 shows various factors that induce changes in ecosystem services around the Okpara dam. 98% of individuals interviewed mentioned that the modernization and extension of the Okpara dam by the Benin national water Company (SONEB) have greatly contributed to the reduction or even disappearance of some ecosystem services around the dam.

A young man from the village of Kika told us:

"These people came to deprive us in the dry season of a precious heritage of our ancestors namely bathing and entertainment in the river. Which is caused by the construction of the dam whose water largely benefits the people of Parakou, far from us." (S.A., kika, August 28, 2019).

This was a frustration noticed among some local residents who think that the dam's development work is less beneficial to them than to people in distant localities. Thus, for more than 95% of these residents, after the development work, certain farming practices are prohibited in a much wider area around the dam. This has had a

negative impact on the production of some crops especially food crops, market garden produce and cotton which are no longer allowed to be produced in the vicinity of the dam. This has led to a drop in local agricultural production and a shortage of essential foodstuffs for the population's subsistence.

Several fishing practices are also prohibited in the place. Prohibited fishing practices include the use of chemical products and/or unsuitable traps. Indeed, the use of unauthorized small-mesh nets and chemical products is commonplace. They negatively impact the availability of fish products. These prohibited practices destroy all aquatic fauna and reduce their availability. Fishing that provides substantial income for nearby people is more and more restricted. Fish are also their main source of animal proteins.

The second main factor is the pressures on tourist and cultural site. The regulation around these sites excluded several people from farming. Consequently, farmers who do not know where to go are taken over these protected areas. Furthermore, they continue to use chemical fertilisers in agricultural production which affects water quality. Indeed, chemicals are drained to the dam that are made of pesticides and other prohibited products. These chemicals are sometimes difficult to remove despite the considerable means deployed by the Benin national water Company (SONEB). As a result, water collected and distributed by SONEB is depreciated by the population and suspected to be the source of certain diseases that affect them. An agent of SONEB declared that

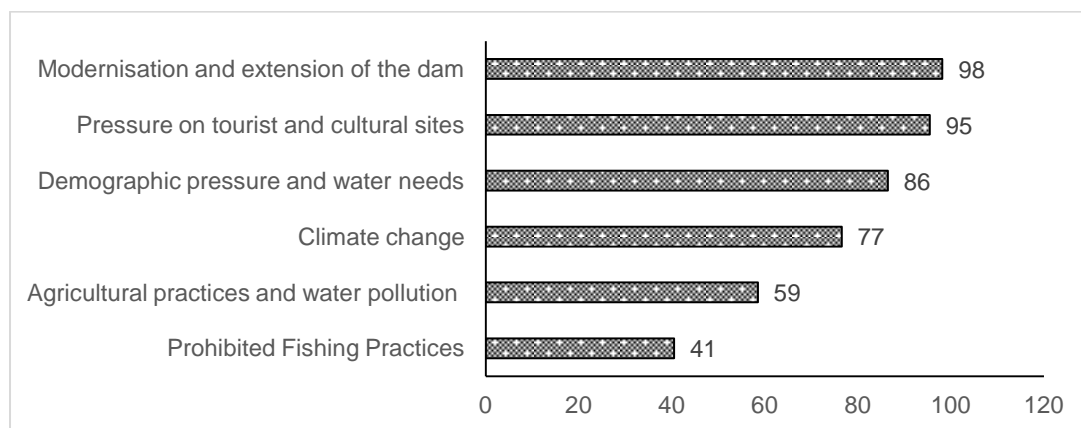


Fig. 3. Explanatory factors of change in ESS around Okpara dam (source: data collected, 2020)

"It is common to hear on local radios that the typhoid fever that widely spread in Parakou in the years 2015-2016 came from the consumption of water from SONEB. That was not true, because the equipment in place limit considerably these risks." (A. T. of SONEB, 12 September 2020).

This situation has weakened certain endogenous practices of adoration of the local gods. One respondent stated:

"Unlike the olden days, our ancestors are getting farther and farther away from us due to desecration of our places of worship by some people in the society who trample on the social norms. So, our prayers are no longer fulfilled like in the past." T.R. said, Kika, 23/07/2020.

That shows the extent to which local people value the cultural events that bring them into communion with their ancestors.

Another important factor that causes changes in ESS is the increase in population.

It appears that the rapid increase of the population and its food needs have resulted in the overexploitation of the river and the degradation of the biodiversity. In the beginning the dam was built to serve at most 25,000 inhabitants but now estimated at more than 150,000 inhabitants. That reflects the pressure on the ecosystem through the reduction of cultivable land and the destruction of fauna and flora with the risk of food insecurity as mentioned by the respondents.

It is worth mentioning that climate change is highly influencing the provision of. Climate changes are perceived by the local population through floods, the disappearance of certain fish species, the change in water temperatures, the variations in water wave currents, the abundance of predators of aquatic species, the decrease in water levels, the drying up of certain water points, the deterioration of water quality etc.

Local population believe that climate change has considerably influenced the balance around the ecosystem by acting on the volume of water in the dam (flooding or receding) and by drastically reducing the potential for agricultural and fishery. Also, the drying up of the dam limits the capacity to supply water for domestic use and consumption. According to the respondents, this

situation caused the water crisis in SONEB's taps between 2005 and 2006.

4.3 Innovativeness of the Riparian Communities in Dealing with the Dynamics of Ecosystem Services Around the Dam

Innovativeness is the ability of a person, a company or a community to evolve, renew or innovate. This implies novelty, creativity and appropriation to impact the daily life of communities. The study showed that several local initiatives are undertaken to better adapt to the new environmental requirements.

The primary innovative action mentioned by more than 85% of the users interviewed is the one that led to the restoration of drinking water supply capacity carried out by the Benin national water Company (SONEB). It has increased the production and storage capacity of water from 7,000 m³ to 35,000 m³ for about 16,305 subscribers. This has considerably reduced the distribution problems often encountered by the company during the dry season. In addition, Water Department and the Technical and Financial Partners have installed drinking water supply systems made up of boreholes for bordering villages that do not benefit from SONEB's water supply. In that sense, one respondent declared

"Even if it is true that we do not directly enjoy water from SONEB, we must have the honesty to recognize in return that the leaders of the country had the good idea to install inexhaustible water points for us for more than 15 years" (I.S. of Kpassa, August 2020).

Apart from that, there are some initiatives regarding the restoration of religious and cultural practices. In a participatory way –including all stakeholders the local population delimited areas of worship to venerate the gods of water and forest [30,31]. There are also some places set for recreation or entertainment. According to them, this allows the restoration of local cultural values that have been lost and the development of tourism as explained by one resident from Kpassa village in these terms:

"We think that these developed sites can attract tourists and bring us money as it happens in some localities of Atacora (in Benin). They receive hundreds of visitors every year and that bring income to the communities which are

organized to welcome tourists who come to enjoy themselves every year. So, entertainment areas are developed in some places for local tourism in this perspective.” (B.S. Kpassa, 22/08/2020).

The populations are aware of the need to develop tourism, which can be not only a source of employment for their offspring but also an opportunity of entertainment for the youth.

In response to certain agricultural and fishing restrictions, the local population has developed adaptation strategies. Most of the population get converted into market gardening by installing boreholes equipped with motorized pumps to facilitate the irrigation of the plantations and fields during the dry season. In addition, dykes are built by these same farmers to facilitate the irrigation of the plantation. According to most of the farmers met at the site, these measures have enabled them to overcome the difficulties of water shortages and to carry out their activities in all seasons and in complete safety. A market gardener met at the site in Kika said:

“ We use our motorized pumps to draw water directly from the dam to the dikes we have built or to boreholes. This allows us to permanently supply our plantations with water during the dry season”. (A.J., Kika, 30/01/2021)

This shows how creative people were in dealing with various changes. With regard to the development of fishing, the practitioners we met confided that they have organized themselves to develop areas along the river downstream where artisanal fishing is developed. This activity supplies the local markets with fish products. To control prohibited fishing techniques, village brigades are set up by the fishermen themselves. They are on duty to discourage bad fishing practices. Fines are imposed on offenders in case of non-compliance with established rules and standards. There are also other initiatives set up to protect some animals from hunting. A group of youth active in the field of ecology is mobilized to raise people awareness on the regulation of hunting.

5. DISCUSSION

Ecosystem services are the benefits that humans derive from ecosystems (MEA, 2005). The different ecosystem services encountered in the case of the Okpara dam water resources are supply services (water for various uses, agricultural products, fishery products), cultural

services (recreational bathing, cultural and religious uses), regulation services (flora and fauna reserves made up of totemic animals or not and plants with various virtues). These services were also cited by [22,32,33] who also identified supporting services in their research areas.

Ecosystem services, while important in meeting the needs of local communities, are under significant threat from human interventions and climate change. These findings concur with those of Wang and al. [34,35,36], who find that ecosystem services are impacted by anthropogenic and climatic actions. Indeed, certain types of land use can reduce the provision of some ecosystem services while they instead enhance another specific service provided by ecosystems [37,38]. Under the pressure of anthropogenic uses, water provisioning services are generally improved, while wild food provisioning services, recreation services, and natural disaster regulation services are shortened [39]. This situation was observed in the Okpara Dam ecosystem case, where the development work carried out at the dam site has improved the provision of drinking water while restricting the provision of all the other ecosystem services to the point that the riparian communities became angry. This suggests that the modification of ecosystems by economic activities, depending on their nature and the land management and allocation patterns they adopt, influences ecosystem services both positively and negatively [40,41]. Each type of ecosystem service corresponds to different functions and services, which in turn depend on the health of the ecosystem, the pressures exerted on it, but also on the use that societies make of it in a given geographical and economic context [42].

Ecosystem services constitute the interface between ecosystems and humans and allow a direct apprehension of anthropogenic impacts on ecosystems through the modification of services rendered and thus impacts on human well-being [43]. The climate changes perceived by the riparian communities through floods and high water level, the disappearance of certain fish species, the change in water temperatures, variations in water wave currents, the abundance of predators of aquatic species, the decrease in water levels, the drying up of certain water points, and the deterioration of water quality have all contributed to exacerbate the disruption of ecosystem services provided around the Okpara dam ecosystem. As with the stakeholders

encountered around the Okpara Dam, those interviewed by Kaboré et al, [44], as part of their research on perceptions of climate change in northern Burkina Faso recognize that climate change represents a major potential threat to the viability of rural households in sub-Saharan Africa that live primarily off of natural resources. Indeed, climate change is causing significant environmental changes, such as recurrent droughts that accelerate the decline of forests in the West African Sahel [45,46,47], reduce vegetation cover and agricultural yields, and promote the expansion of bare areas [48].

To adapt to change and build resilience to the degradation of ecosystem services, the traditional practices and knowledge of local communities are essential [42]. To design and implement agroecological production systems, farmers rely on a panel of knowledge (scientific, local, expert) related to their natural environments and their functionalities [49,50]. Around the Okpara dam in North Benin, several innovative actions have been developed by communities to restore and sustainably conserve the flora and fauna around the dam, improve agricultural and fisheries production, and improve water supply capacity for various community uses. In order to limit the degradation of ecosystem services, an active water resource management policy is required as well as innovations, particularly in infrastructure services, which are based on a whole range of artificial technologies deemed to be able to respond to all the problems, both quantitative and qualitative, posed by water resource management today [51]. However, in the case of Okpara, the populations are very little involved in the decision of the external interventions undertaken. Dams also have a social impact that affects sustainable development of the inhabitants if the interventions are not carried out under the best conditions with the involvement of the riparian communities. This infrastructure also contributes to the destruction of several hectares of land that are used to feed thousands of people in the surrounding communities [52].

6. CONCLUSION

The various ecosystem services provided by the Okpara dam justify the attention that this ecosystem requires. Indeed, the ecosystem around the Okpara dam is an important source of drinking water and of a wide range of agricultural and fishing products. The riparian communities consider the dam as a space for recreational

bathing, leisure, and the expression of cultural and cultural activities. This ecosystem is also recognized as an ecological reserve that abounds in animal and plant species that contribute to the balance of nature. The development work undertaken by the Benin national water company (SONEB) has made it possible to increase the production capacity of drinking water to supply the nearby city of Parakou, but at the detriment of the riparian communities who do not yet benefit from the services of this company's intervention. In addition, this intervention has severely disturbed the livelihood of farmers, fishermen and religious dignitaries whose activities have suffered of the environmental requirements to be respected imposed around the dam. The effects of climate change have greatly exacerbated the impacts of this intervention. However, riparian communities have developed resilient capacities to cope with the situations and adapt their livelihood. The study recommends that interventions that impact natural resources should analyse the context of the resources, the livelihood of the riparian communities and involved the latter to carry out good quality interventions that have positive impacts both on the ecosystem services and riparian communities.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

CONSENT

As per international standard or university standard, respondents' written consent has been collected and preserved by the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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