



Spatial Analysis of the Mode of Management and Conflicts of Use of Water Resources in the Watershed of the Lobo River in Nibehibe (Central-Western Côte d'Ivoire)

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Authors' contributions

This work was carried out in collaboration among all authors. Author TFF designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors KWAB and DA managed the analyses of the study. Authors YAB, KTJJ and KM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Water is an indispensable resource for all activities developed by man. Water resources are indispensable for the survival of the populations of the Lobo watershed in Nibéhibé. They offer many multidimensional services. Around these important resources, social actors have different ways of perceiving them. This is why their management comes up against a difference in logic and action on the part of the different stakeholders. Thus, it must be noted that there is a crystallization of social relations between the different groups of actors involved and this is based on conflicts of

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use and the intensity of water scarcity. The objective of this study is to show the relationship between management mode and conflicts of use of water resources in the Lobo watershed in Nibéhibé. To achieve this objective, the methodology was based on the triptych documentary research, interview and questionnaire survey. The documentary research consisted in defining the contours of the subject in order to better understand it. Then, the interviews carried out with the actors of the water sector in the Lobo basin made it possible to collect information on the perception and the mode of management of the water resources in the basin. Finally, using the simple random selection method without discount and the use of a statistical equation, a sample of 384 households spread over the entire catchment area served as the basis for our surveys. Population surveys, combined with spatially referenced data under a GIS, have made it possible to map the spatial distribution of water supply sites on the one hand, and the spatial distribution of water-related conflict types on the other. The results show that the population has a wide variety of water supply sources. Moreover, the current management mode is either liberal (or private) or participatory (or community-based) depending on the type of water resource (surface or groundwater) and on the perception of the actors with regard to water. Thus, the different uses generate conflicts that are perceived between cultural actors (indigenous) and economic actors such as SODECI (Water Distribution Company in Côte d'Ivoire) and fishermen (non-indigenous). There are also conflicts between women, which can be summarized as disputes over water points and distrust between different communities. An integrated management of water resources in this watershed would therefore be beneficial to all stakeholders.

Keywords: Conflicts of use; integrated water resources management; Lobo watershed; spatial analysis, water supply.

1. INTRODUCTION

Water is a limited and vulnerable resource, essential for life, development and the environment [1]. It is a vital issue in all countries of the world. Therefore, Water resource is one of the major public assets which is a critical need for human wellness. Water use can be mainly divided for agriculture, industry and domestic supply as well as maintaining ecosystem, of which these usage and maintaining should be in equity in terms of quantity and quality [2]. According to [3] water governance and stakeholder engagement should be researched for their role in formulating and implementing solutions to critical global water issues. In Côte d'Ivoire, the stakes of water management are high because the development of almost all sectors of the national economy is dependent on water resources. It is therefore imperative that sustainable management of water resources be integrated into Côte d'Ivoire's development programs in order to achieve long-term economic and social development [4]. However, water resource management faces both hydrographic and social interactions that have led to competition and conflict, making resource management a framework where different viewpoints among stakeholders in the stewardship process are manifested and where very different environmental, socio-economic and cultural interests, values and processes confront

each other [5]. The idea that stakeholders have of the water resources in a watershed is directly related to the way in which these resources are managed. In the Lobo watershed, each sector of water use, i.e. agriculture, drinking water supply, pastoral hydraulics, mobilizes the quantities it needs to satisfy its needs, without worrying about the needs of other sectors or the long-term survival of ecosystems [6]. Also, it must be noted that this watershed is characterized by a crystallization of social relations between the different groups of actors involved. This crystallization revolves around conflicts of use and the intensity of water scarcity. It thus appears opportune to understand the origin and intensity of these conflicts related to the mode of management of water resources in order to possibly propose solutions for its perpetuation. This will require the collection of quantitative and qualitative data through a field survey among the actors of these water resources. The constitution of a reliable database is the guarantee of a healthy appreciation of the relations that the populations maintain around water resources. Thus, within the framework of this study, it is a question of showing the relationship between the management mode and the conflicts of use of water resources in the catchment area of the Lobo river in Nibéhibé through a spatial analysis. Indeed, a precise analysis of the spatialized information by a spatially referenced information system can allow to evaluate the modes of

management of water resources and the extent of conflicts with regard to socio-cultural considerations.

2. MATERIALS AND METHODS

2.1 Study Area

The Lobo watershed is located in central-western Côte d'Ivoire between 6°17' and 6°44' W longitude and between 6°46' and 7°41' N latitude (Fig. 1). It drains an area of 7,000 km² with an outlet at Nibéhibé. This watershed has a catchment area that is not circumscribed within a single administrative entity. Most of the basin covers the departments of Daloa, Issia, Vavoua, and Zoukougbeu. The Lobo river has its source at an altitude of 400 m south of Séguéla and flows into the Sassandra river not far from the locality of Loboville. The town of Daloa represents the economic pole of the region.

2.2 Data Collection

The data concerns information on the management method and the perception of the users of the water resources in relation to the existing conflicts in the different localities. These data were collected through a questionnaire survey and interviews conducted with stakeholders in the Lobo watershed whose outlet is in Nibéhibé. For this purpose, a GPS (Global Positioning System) of Garmin brand was used to take the geographical coordinates of the localities and water resources in order to spatialize them. A digital camera was used to take pictures as well as survey questionnaire sheets. The field surveys were carried out in two phases: a first phase devoted to households and a second phase devoted to state structures such as the Water Distribution Company in Côte d'Ivoire (SODECI) and the Territorial Direction of Hydraulics (TDH) of the Daloa region. These surveys, carried out between March and April 2019, involved 30 localities based on accessibility and spatial distribution criteria, with a heterogeneous and cosmopolitan population composed of indigenous (Bété, Niamboua, Yandeboua), non-indigenous and non-native people. We chose open-ended questions because they have the advantage of raising new questions and broadening the debate. Individual interviews with heads of households were conducted based on indirect and direct questions. In order to conduct this survey properly and in the impossibility of surveying all households, sampling was necessary. We used

a simple random sampling method without discount [7]. It should be noted that the sampling technique used the method of reasoned choice and proportionality. Knowing the total number of households in the catchment area and the number of households per locality, this technique appears to be the most appropriate method for determining the sample of households to be interviewed for this study. Thus, for a confidence level of 95%, according to the reduced centered normal distribution, the sample size (n) for each locality was determined using the following formula:

$$n = \frac{(z\sqrt{pq})^2}{c^2}$$

n = Representative sample size

z = Confidence level

c = Margin of error

p = Proportion of households that are assumed to have the characters you are looking for.

This proportion varying between 0 and 1 is a probability of occurrence of an event. If no value for this proportion is available, it is set at 50% (0.5) and q = 1 - p. Assuming p = 0.50 then q = 0.50. For a 95% confidence level, z = 1.96 and the margin of error c = 0.05. Thus, after calculation, the total number of households to be interviewed is 384 households spread over the entire catchment area.

2.3 Data Processing

The processing of the various data collected through our questionnaire and guide, required the use of Excel and ArcGIS software. Indeed, the demographic and statistical data were processed by the Excel spreadsheet to produce tables and graphs. As for the ArcGIS software, it was used to facilitate the processing of shape files containing the boundaries of the Lobo watershed in order to extract the study area and the different localities. It was also used for the realization of the different thematic maps.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Water supply sources

Surveys have revealed that, to meet water needs, populations rely on both surface and groundwater.

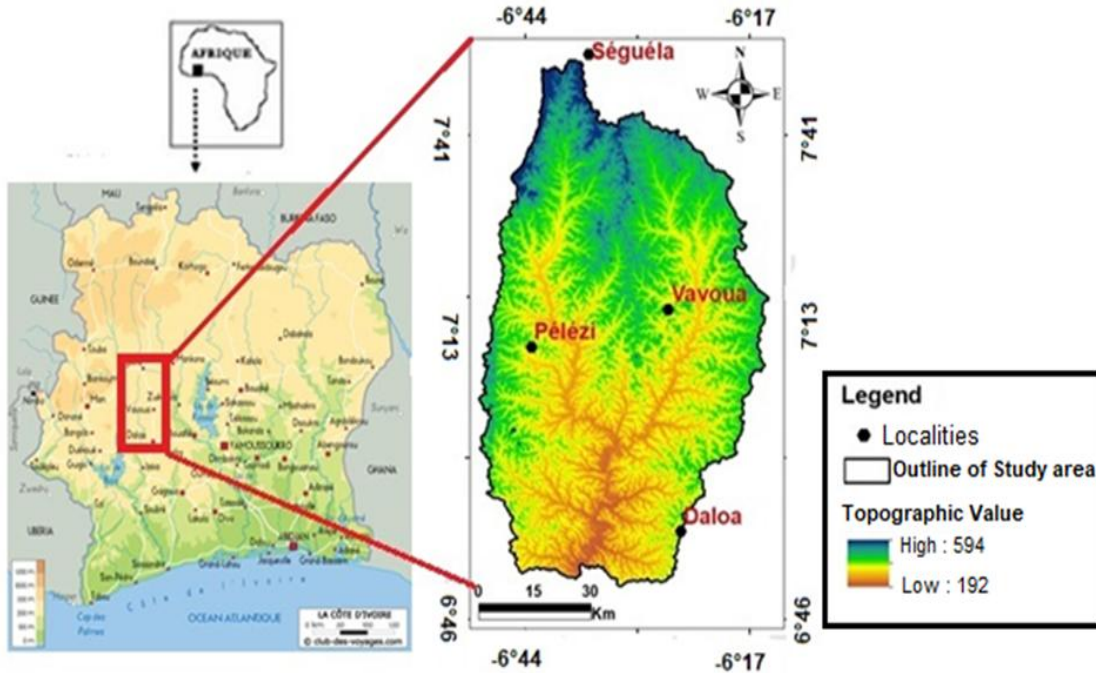


Fig. 1. Location of the study area

Groundwater resources include traditional wells, village hydraulics (VH), improved village hydraulics (AVH), and developed water sources (Fig. 2). This groundwater is mainly the source of water supply for the rural population.

As for the surface waters useful to the populations' needs, they are represented by rivers, hydro-agricultural dams, marigots and lakes (Fig. 3).

Fig. 4 presents a spatial distribution of rivers and hydro-agricultural dams used in the daily life of the populations.

In Fig. 4, we have an overview of the distribution of the different water resources on which there are intense anthropic actions with a

concentration of these waters developed downstream of the watershed. Thus, in the localities of Yuala, Kibouo and Brakaguhé there are dams. It should be noted that the river most in demand is that of the village of Zahia, more precisely in the villages of Zimeguhé and Château known as "Tchrato". This river is located 25 km from the town of Daloa (urban area) and is the source of drinking water supply (DWS) for the said commune. In addition to the latter, the river of Zaibo is also used by the surrounding populations.

Moreover, the surveys have revealed that for household water supply, within the watershed, different water sources at the urban and rural scales are mobilized, sometimes with resource associations (Fig. 5).



Fig. 2. Groundwater supply source

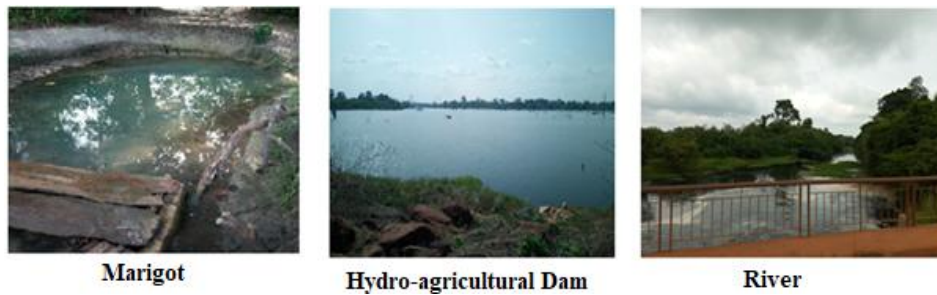


Fig. 3. Source of surface water supply

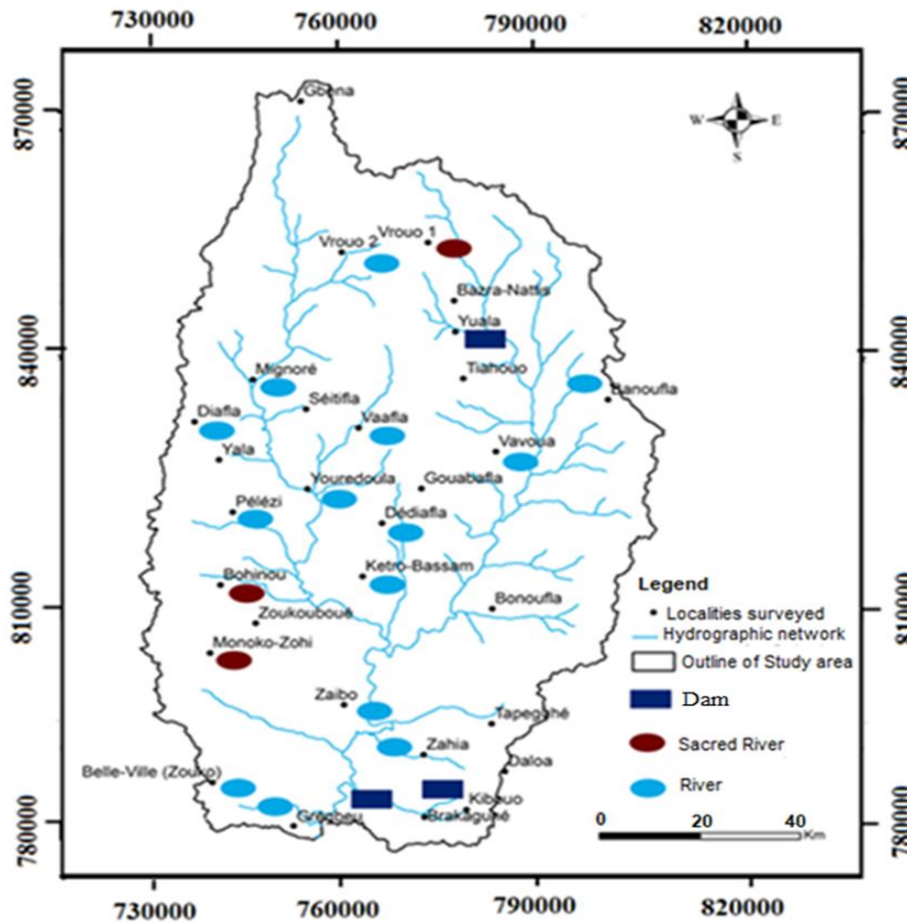


Fig. 4. Spatial distribution of surface water sources (hydro-agricultural dams and rivers) on the catchment area use by people

Groundwater resources are divided between traditional wells, village hydraulics (VH), improved village hydraulics (IVH) and natural water sources. This groundwater is mainly the source of water supply for people in rural areas. The use of this water is mainly intended for domestic activities, whose consumption constitutes

the main need, regardless of the type of resource.

As for surface waters, they concern hydro-agricultural dams, rivers, marigots and lakes. Fig. 5 presents a spatial distribution of rivers and hydro-agricultural dams used in the daily life of the populations.

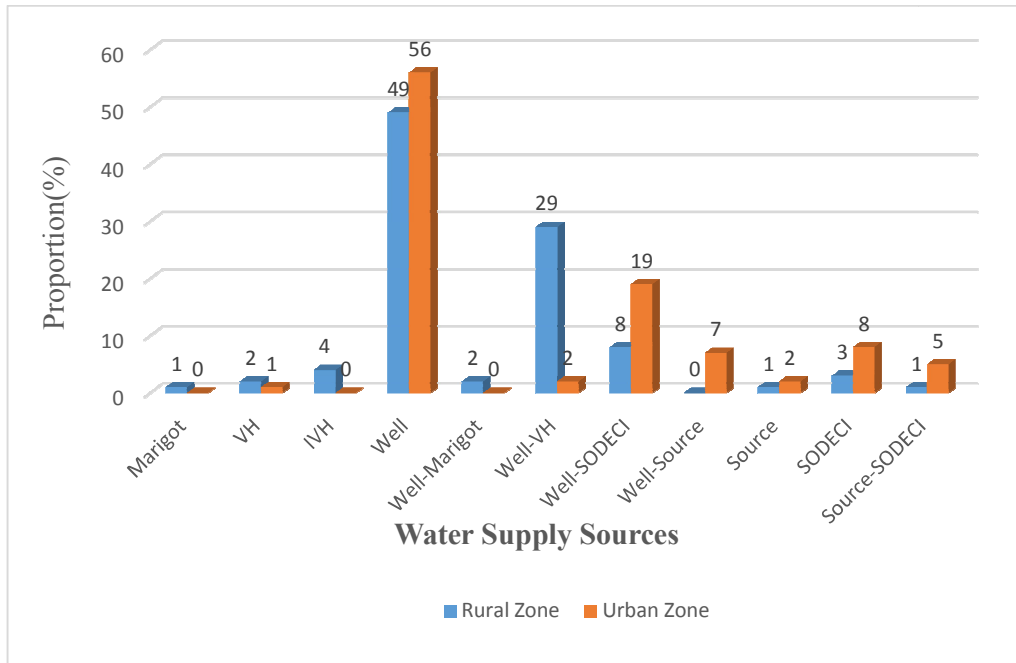


Fig. 5. Proportion of Water Supply Sources by Rural and Urban Areas

3.1.2 Mode of water resources management

In the Lobo River basin, there are two types of management: liberal (or private) management and community (or participatory) management.

3.1.2.1 Community Management

It is a well-developed local or traditional management that allows the different users to be involved in one way or another in the management. This community management of water is organized by village committees, which generally perceive water as a common good and a source of life. In this sense, its management deserves a great deal of attention in order to have it available at all times for their multiple needs. It concerns most of the water resources (Fig. 6). However, these management committees are more important around village hydraulics and improved village hydraulics (Fig. 6).

The analysis of Fig. 6 also reveals that at the level of the dams, of the three sites, only one has no management committee (Kibouo). As for the marigots and managed natural springs, there is management, but in very small numbers in all of the areas surveyed. This management consists of the maintenance of water sources and the

maintenance of law and order in order to avoid potential conflicts over water. Less remarkable is the management of rivers. There is really no way to manage this resource. All these elements highlight, in general, the individual and uncoordinated use of water in the watershed.

3.1.2.2 Liberal management

This form of so-called liberal management is organized by households to have water available at any time and to ensure that cleanliness is maintained around these water points. Furthermore, it is important to note that this organization does not benefit in practice from a management mode or a role assigned to each user for its management (Fig. 7). There is therefore no consultation in the management of these water points. Each user uses it as much as he wants to meet his daily water demand.

In this graph (Fig. 7), these are the households that responded that they do not have a management committee for certain water supply points. Analysis of the graph shows that 65% of the households surveyed believe that they do not have a well management committee, compared to 19% of those who use both well and SODECI water, 6% for SODECI only, 4% for alternating

between wells and SODECI, 3% for alternating between source and SODECI, 2% for source only and 1% for alternating between wells and HV which they use as water supply sources. The management of these water points is liberal.

3.1.3 Conflict of use of water resources related to water perception

3.1.3.1 Water uses

The water resources of the Lobo watershed are used for several purposes. These include agriculture, fishing, drinking water supply and cultural practices (Fig. 8).

Throughout the basin, these different categories of use are not distributed in a uniform manner and all resources are not subject to the same uses. Thus, at the level of the Zahia River, the four (4) main uses of the water resource are observed. Let us note that this river answers divergent needs which are among others related to the cultural practice, the agricultural activity, fishing and also to the supply of drinking water of the commune of Daloa by the SODECI. On the other hand, at the level of Zaibo we find three (3) types of use (drinking water supply, agriculture and fishing). In the localities of Bohinou, Vrouou 1 and Monoko-Zohi, water is considered sacred and is used for cultural purposes. As for the Yuala, Kibouo and Brakaguhé dams, water is used for both agriculture and fishing. However, in most parts of the watershed the water is used for

agricultural purposes. Table 1 presents a summary of the different actors and users of surface water.

Table 1 reveals that the Tchrato River records several actors, namely SODECI, indigenous people, fishermen and farmers with divergent usage logics. In addition, it should be noted that SODECI and some fishermen (Bozo) depend solely on this river, which is why they are intensifying their activities there.

3.1.3.2 Water heritage value of water resources to natives

For indigenous people, water resources are a land heritage. They make these resources their own because they feel they are the first people to live around these resources and therefore have the right to have real control over these water resources. This perception is generally observed in almost all localities that are in contact with these waters. For indigenous people, these water resources have sacred values. It is the place where the gods and ancestors live and dwell. This reality is based on the fact that they are the only ones to make adoration, libations and cultural practices around water. There is also the element of protection and happiness that water represents for these natives. This easily justifies the importance that these peoples give to all the water resources in the basin.

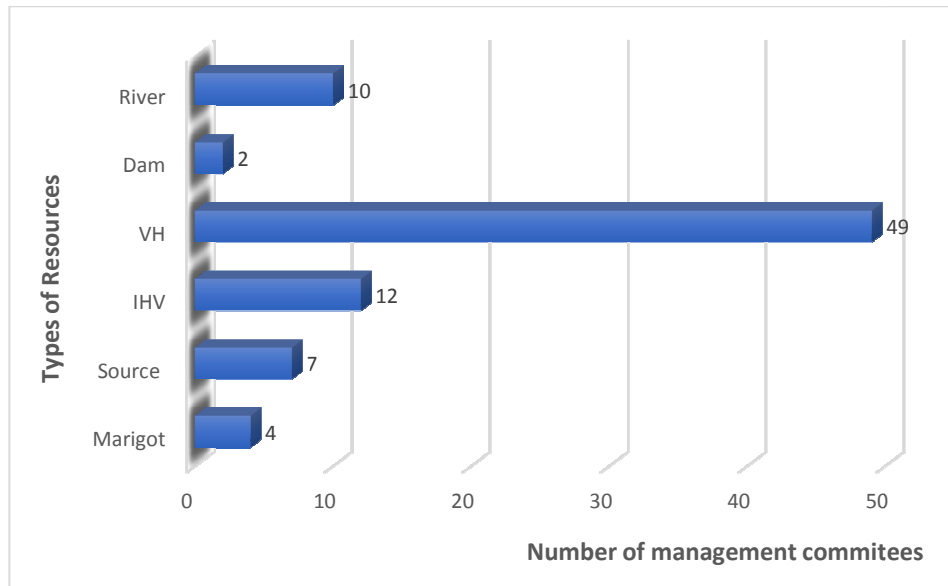


Fig. 6. Proportion of community management committees by types of resources

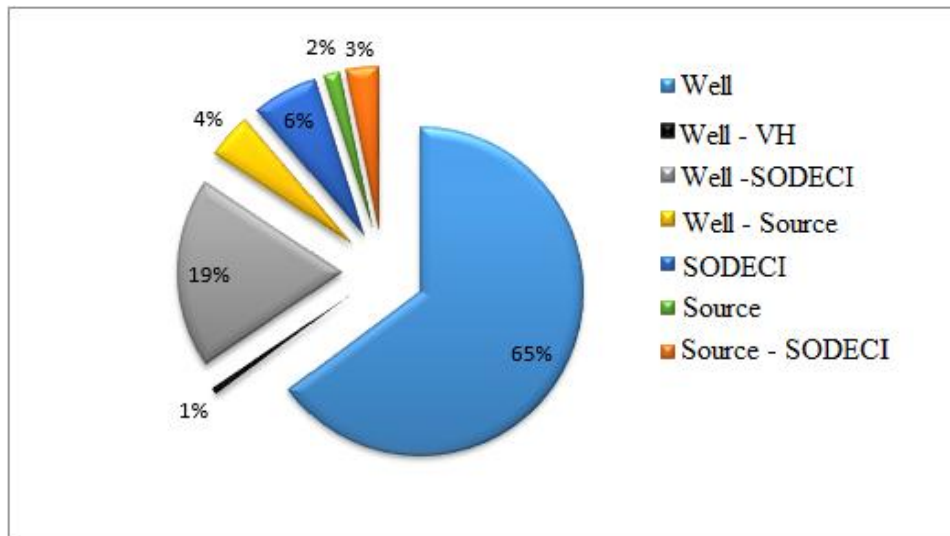


Fig. 7. Proportion of water points under liberal management

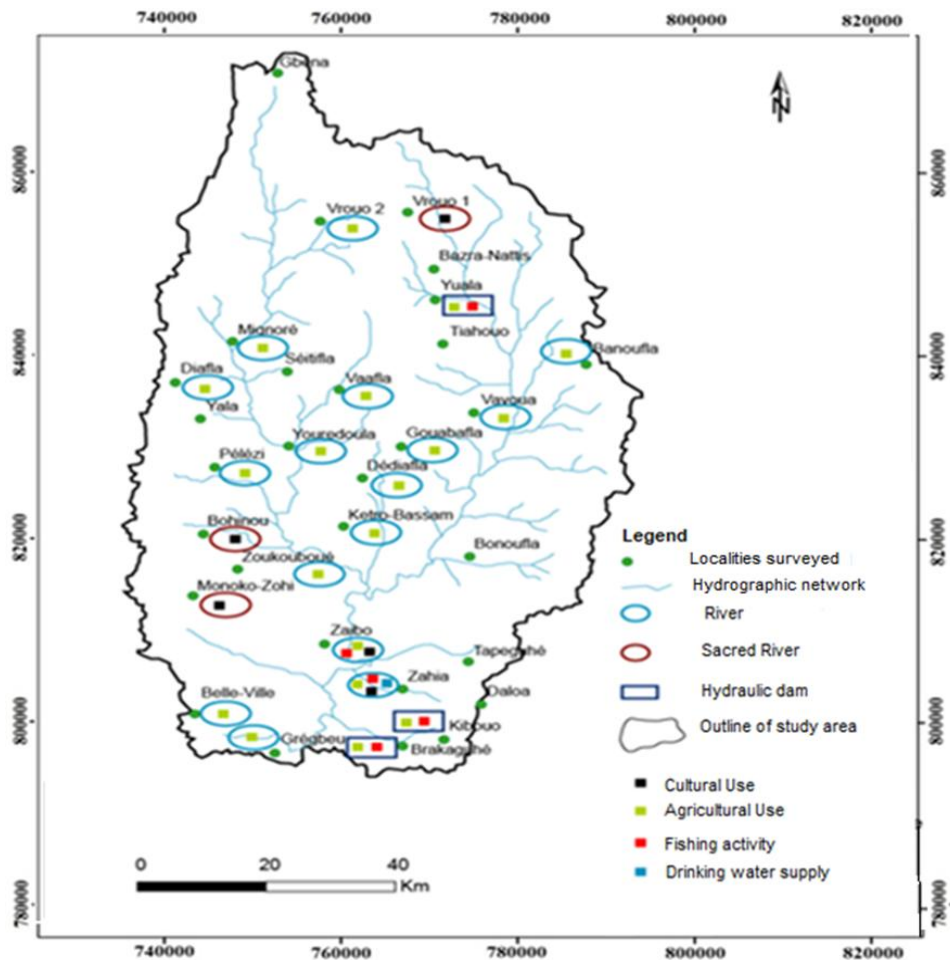


Fig. 8. Map of the spatial distribution of surface water resources and different uses

3.1.3.3 Economic stakes of the Tchrato river for SODECI

The Tchrato River is a resource that is perceived differently by SODECI. For it, the land is the exclusive property of the state, which gives it the right to control everything on it, including water resources. Therefore, the state can use it to meet the needs of the population. Thus, for this company, the water resource is not the property of rural communities or the populations around the water. As a result, it does not find it necessary to have the agreement of a local community before setting up its activities. Moreover, behind this concern to satisfy the needs of the populations in terms of drinking water, is the economic character that water constitutes for SODECI. Indeed, in its drive to meet the needs of the population, SODECI provides households with meters for a fee. Subsequently, bills are distributed to the population according to their different consumptions. This reality justifies the economic interest that water represents for this company. This form of perception of the resource is different from that of the indigenous people.

3.1.3.4 Water resources as an economic value among fishermen (Bozos)

The fishing activity is carried out for commercial or economic purposes on hydroelectric dams and also on rivers to which the natives attribute a patrimonial value. In general, we find these fishermen (Bozos) around the different resources of the basin with a high concentration in Zahia (Zimeguhé, Castle) and in Zaibo (Sikaboutou).

For these fishing communities, water is an economic asset. Indeed, the Bozos live from the fishing activity that they practice all the time. Therefore, they invest considerably in order to provide for all their needs.

3.1.4 Manifestation of conflict of use

Water is a universal good and a collective natural resource. However, it can also be used as a private good. In view of the importance of this natural resource, it attracts many users with divergent interests. At the level of the lobo watershed in Nibehibé, the sources of conflicts between the different actors are, on the one hand, cultural (indigenous people) and on the other hand, economic (farmers, fishermen and SODECI). All these entities have different perceptions of water resources. Thus, most of these conflicts stem from the use of water for divergent purposes and the absence of a regulatory framework adopted by all stakeholders. Fig. 9 shows the spatial distribution of surface water conflict cases over the entire watershed.

Fig. 9 shows the conflicts we observe in the basin. The cases of conflicts are perceived in the zones of Zahia, more precisely in the locality of Zimeguhé around the Tchrato River, which records two main types of actors and these show divergent interests of uses, source of social imbalance. This situation of conflict is not observed at the level of other water resources. Indeed, the absence of cases of conflict is explained by the fact that the indigenous people of these different places have, on the whole, the

Table 1. Summary of the different uses of water resources in the Lobo watershed according to the actors

Actors	Interest of the exploitation of water resources	Activities practiced	Frequency of activity	Sites of realization
Natives people (Bété, Niamboua, Yandeboua, Gouro)	Social	Domestic activities	Daily	Home
	Cultural	Subsistence fishing	Daily	River; Lowland
		Seasonal fishing	Periodical	River
Economic	Adorations, rituals, libation	Periodical	River	
		Agricultural activity (market gardening, irrigated rice)	Daily	River; Dam; Lowland
Allochtones (Baoulé and other)	Social	Domestic activities	Daily	Home
	Economic	Agricultural activity (market gardening, irrigated rice)	Daily	River(Tchrato); Dam; Lowland
Allogens (Bozo)	Social	Domestic activities	Daily	Home
	Economic	Fishing for profit	Daily	River (Tchrato)
SODECI	Economic	Drinking Water Supply	Daily	River (Tchrato), Borehole

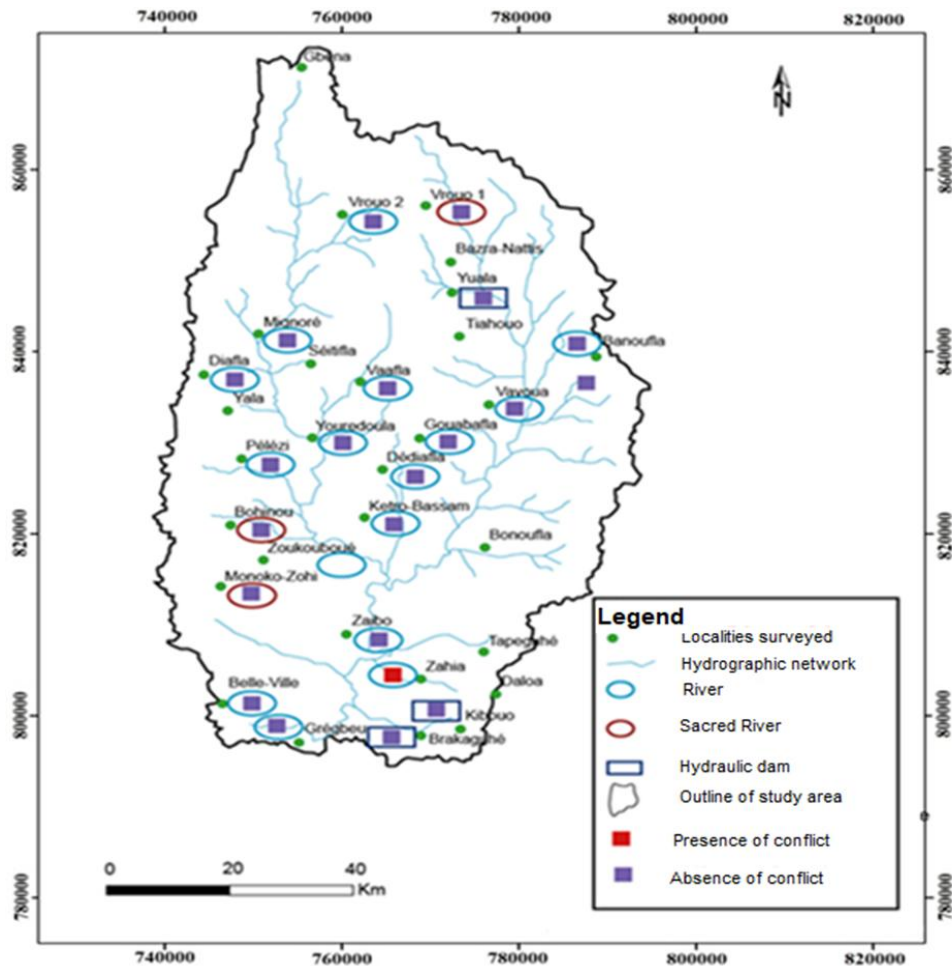


Fig. 9. Spatial distribution map of surface water use conflicts in the basin

control of the bodies of water which are managed, generally, by the chiefs of land on the basis of certain principles imposed on the users, namely: for a harvest of ten (10) bags of rice, the farmers hand over one (1) bag to the landowners. Also, fishermen pay a sum of 9 US dollards per fisherman to have access to the water body. In addition, on certain bodies of water such as the Yuala Dam, participatory management is ensured by the different villages that share the body of water (Dérageon, Bazzra, Yuala and Brouafla). Thus, each village takes a critical look at the use and management of the water body and contributes to better management.

The results of the study relating to conflicts are summarized according to the conceptual diagram (Fig. 10) which presents the causes and effects of these conflicts.

3.2 Discussion

3.2.1 Method of water resource management

On the Lobo watershed we record a set of water resources including surface water composed of dams, rivers of the marigots and lakes with which the populations are in contact and make use of. Next to this, we have the underground water, namely wells, village hydraulics, improved village hydraulics, standpipes and natural water sources that have been developed. Thus, in order to obtain water, the different households use these different water sources for their daily water needs with a dominance of well water. With regard to these different water resources, the populations of the catchment area adopt a set of methods for the management of water resources. Thus, we distinguish two types of management which are, on the one hand, a liberal or private management

for the major part of the wells and on the other hand a so-called participative or community management which includes a set of actors gathered in a management committee. This form of management is useful because certain uses can have an impact on the resource and compromise both the proper functioning and management of the natural environment and the other uses that depend on it [8]. As far as liberal management is concerned, there are really no established rules for its management. This form of management most often consists of the execution of orders to keep the water point premises in adequate hygienic conditions. These results are in line with those of [9], who in his studies emphasizes that individual water management is observed at the level of water points (wells and boreholes). It is organized by the households in order to have water available at all times and to ensure that cleanliness is

maintained around the wells and boreholes. Moreover, for [10], it is rather a question of endogenous management, that is to say, the way of management in an environment without external interventions. In other words, it is the set of knowledge, beliefs, exploitation practices and adaptation strategies of a community of men (a socio-cultural group) concerned by the ecological potential in question. Finally, for [11] the process of water resource management is a complex domain to master for several reasons: multiplication and concentration of uses in a situation of interdependence, diversity of the socio-economic organization of users, opposition of systems of representations and diverse perceptions that impact the use and management process of water resources. Thus, the collaborative approach for sustainable management of watersheds is built on engagement of diverse stakeholders [12].

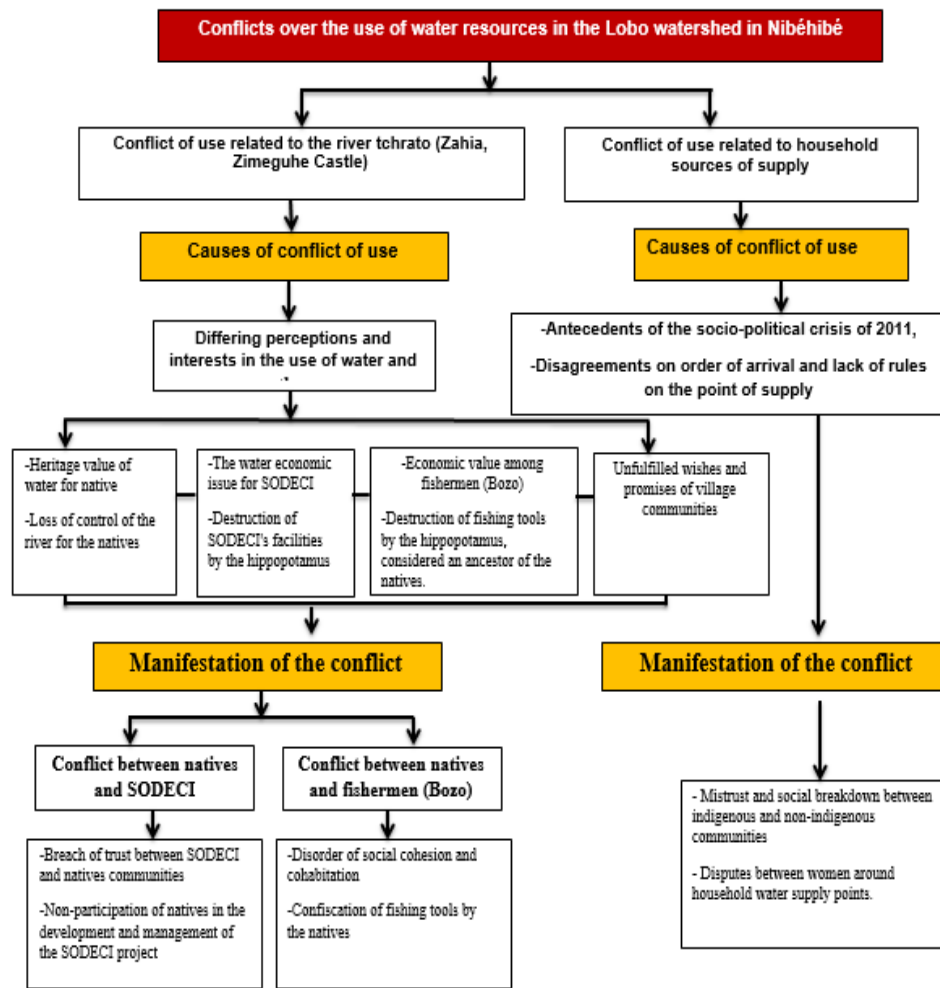


Fig. 10. Conceptual diagram of water resource use conflicts in the Lobo watershed at Nibéhibé

3.2.2 Conflicts over the use of water resources

According to [13], the multitude of watershed planning and management objectives inevitably leads to conflicts among watershed stakeholders, or interest groups. In deed, the competitive and divergent use of water resources at different water points is a source of conflict in some localities in the basin. There are some cases of source conflicts (VH and IVH) that can be summarized as mistrust. On the other hand, other cases of conflicts are related to surface water. This is notably the case of the Tchrato River in the locality of Zahia between the cultural actors (indigenous) and SODECI considered as an economic actor. Indeed, very often conflicts break out between SODECI and the indigenous populations because of the presence of the hippopotamus in the Tchrato River. This animal constitutes a real danger to the lives of SODECI agents in the exercise of their work. Also, this hippopotamus is at the origin of many damages to SODECI's equipment. For their part, the natives cannot imagine that SODECI could sell them water, because this water is their heritage. They also deplore the very high cost of the water meter and find the water bills exorbitant. Consequently, they consider that the damage caused by the hippopotamus is a sign of its anger, and therefore SODECI must pay an almond to calm the anger of the animal they consider their ancestor. This social unrest is said to be at the root of the frequent shortages of drinking water supply to the population of Daloa whose treatment plant is located on the Tchrato River. In addition, there are cases of conflicts between indigenous people and fishermen (Bozo). To this end, it happens that the fishing equipment of the non-natives is confiscated by the natives or destroyed by the hippopotamus present in the water. Also, the allogènes see in this animal a mysterious spirit because it only harms the foreign community. This favors attitudes of distrust of these fishermen towards the natives. This result corroborates the work of [14], which for them, where water is perceived as a community heritage on the one hand, following social and cultural precepts, it is also conceived as an economic asset for certain socio-professional categories and the public hydraulic services, whose work is oriented towards the principles of general interest. This explains the most often contradictory representations around water resources, which are the source of social imbalance. They continue in this vein by showing that conflicts are frequently linked to the increase

in the number of users and the diversification of uses, which are interdependent aspects. This is a reality that the Lobo watershed is no exception. Similarly, [9] addressing this issue in the locality of Mbomboye (Senegal), points out that the demand for water is increasing sharply in this rural world, which creates competition between the various water users and managers concerned, sometimes disturbing the social balance. He continues his argument by showing that conflicts often arise under conditions of misunderstanding created by the users of the water resource, each of them trying to protect these interests as best they can. However, our results show that water-related conflicts are rooted in the competitive use and divergent perception of water by the different actors. Moreover, for [15] population growth, climate disturbances and its consequences, such as drought, desertification, soil poverty, water scarcity and pasture degradation are often cited as the main causes of conflicts between farmers and pastoralists. Moreover, [16] demonstrates in his work that water management which is sometimes transboundary leads to conflicts between some countries. This is what [17] highlights in his work which illustrates the Cameroon-Nigeria conflict. In fact, this border conflict is related to the geo-economic (control of trade flows and their repercussions) and geopolitical (control of migration and territorial integrity) issues related to access to the waters of Lake Chad. Also, [18] agree in the same vein by evoking the problems of conflict in the watershed of the Nyabarongo Rivers in Rwanda, which is a transboundary water between 11 countries.

4. CONCLUSION

In short, let us remember that the different modes of water resource management, characterized by a management that is either community-based or liberal with multiple interests, constitute a threat in the context of sustainable management of these resources. Indeed, water consumption is increasing year after year and is accompanied by a strong divergence in the use of the available water as well as by many players with different operating objectives. This threat makes its use dangerous and disrupts social cohesion, which leads to social unrest between the different actors of the water resource, namely the natives, the SODECI and the fishermen. In view of all these realities facing the Lobo watershed, it is necessary to think differently about the management of the

water resource. It will have to be part of an integrated water resource management approach to the detriment of sectoral management for a rational, equitable and sustainable use of water resources in this watershed.

CONSENT

As per international standard or university standard, participant's written consent has been collected and preserved by the author(s).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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