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ASSESSING THE ADAPTABILITY OF A RIVER CONTRACT IN THE CATCHMENT AREA OF THE KALAMU RIVER AT BOMA (KONGO CENTRAL, DEMOCRATIC REPUBLIC OF THE CONGO)

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Résumé

Cette étude évalue la faisabilité d'une démarche de contrat de rivière dans le bassin versant de la Kalamu, à Boma. La méthodologie s'appuie sur une analyse documentaire, des observations de terrain, des enquêtes, ainsi que des analyses physico-chimiques et microbiologiques des eaux. Le bassin subit une pression anthropique intense, aggravée par les inondations de novembre 2015 et de décembre 2016, qui ont engendré des pertes humaines et matérielles considérables. Si les paramètres physico-chimiques indiquent une qualité de l'eau globalement acceptable pour certains usages, les analyses microbiologiques révèlent une forte contamination par des coliformes totaux, fécaux et *Escherichia coli*, soulignant un risque sanitaire majeur pour la consommation humaine. L'atelier a rassemblé 82 participants, incluant des autorités urbaines, des services techniques, la société civile, des représentants des communautés et des usagers clés. Lors de l'atelier participatif, divers enjeux ont été soulevés : pollution, érosion des berges, ensablement, déforestation, dégradation des écosystèmes et risques d'inondation. Les parties prenantes ont manifesté leur souhait de maintenir le dialogue et de participer activement à la création d'un comité de rivière. L'analyse SWOT souligne des points forts, notamment l'implication des pouvoirs publics et l'existence d'un cadre réglementaire. Les priorités d'action portent sur le drainage, l'entretien du cours d'eau, la gestion des déchets, le suivi de la qualité de l'eau, la réhabilitation des berges et les actions de sensibilisation.

Mots-clés: Contrat de rivière, Adaptabilité, Bassin versant, Rivière Kalamu, Ville de Boma

Abstract

This study assesses the feasibility of a river contract scheme for the Kalamu catchment area in Boma. The methodology is based on a literature review, field observations, surveys, and physico-chemical and microbiological analyses of the water. The catchment is under intense anthropogenic pressure, exacerbated by the floods of November 2015 and December 2016, which caused considerable loss of life and property. Whilst the physico-chemical parameters indicate that water quality is generally acceptable for certain uses, the microbiological analyses reveal high levels of contamination by total coliforms, faecal coliforms and *Escherichia coli*, highlighting a major health risk for human consumption. The workshop brought together 82 participants, including local authorities, technical services, civil society, community representatives and key stakeholders. During the participatory workshop, various issues were raised: pollution, bank erosion, silting, deforestation, ecosystem degradation and flood risks. Stakeholders expressed their desire to maintain dialogue and to play an active role in setting up a river committee. The SWOT analysis highlights strengths, notably the involvement of public authorities and the existence of a regulatory framework. The priorities for action focus on drainage, river maintenance, waste management, water quality monitoring, riverbank rehabilitation and awareness-raising initiatives.

Keywords: River contract, Adaptability, Watershed, Kalamu river, Town of Boma

1. Introduction

The river contract is a tool for integrated and participatory water management at the local level, but with a universal scope [1]. Thanks to this innovative and collaborative management approach, public and private partners, brought together within a river committee, consensually and

voluntarily define an action programme aimed at restoring the multiple functions and uses of water at the watershed level [2], [3]. The river contract is an integrated water resources management (IWRM) tool, an approach considered by as a new paradigm for water operators [4]. This new approach is part of the current context of the Kalamu river basin in Boma.

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The town of Boma, located in the province of Kongo central in the Democratic Republic of Congo (DRC), is drained by the Kalamu river at Boma. Like a number of other towns in the DRC, Boma is undergoing demographic growth, which is forcing it to sprawl without a sanitation plan, in the absence of a wastewater and excreta treatment center, or a solid waste landfill [5]. However, before independence, the town of Boma was equipped with rainwater gutters that have fallen into disrepair and even been destroyed, despite the town's development, due to a lack of appropriate town-planning standards.

The Kalamu river receives an average annual rainfall of 870.6 mm. The gutters in the town of Boma need to be rehabilitated, rebuilt and/or resized to contain the life cycle of the Kalamu river. The need for better management of the Kalamu river is all the more imminent as the demographic growth of Boma without urban planning standards is having abusive consequences on the exploitation of soil, water and plant resources around and in the Kalamu river, thus causing a profound change to the environment [5], [6]. What's more, in the new extensions to the town, there are virtually no rainwater or wastewater drainage systems. Uncontrolled urban development is at least partly to blame for the seriousness of the flooding, and it has become more and more common for uncontrolled urban development to take place in non aedificandi areas. The deterioration of stormwater drains is due to the fact that they are clogged with household waste. The lack of cleaning of the river's minor bed and maintenance of the obsolete drainage system in the town of Boma are causing numerous problems, such as loss of wetness, silting and recurrent flooding. In addition, the river Kalamu, the town's main watercourse, has become a dumping ground for various types of municipal waste, acting as a public dumping ground for the local population [7].

However, the water from this river is used by part of the population for various household chores (washing clothes and dishes), cleaning motorbikes and cars, especially market gardening and swimming. This exposes the population to a range of water-borne diseases, including diarrhoea, typhoid fever and malaria, not to mention a number of other opportunistic infections that are preventable. Urban areas are therefore exposed to insalubrity, making it difficult to find solutions and compromising the health of ecosystems [5], [8].

The accumulation of waste in unauthorised dumps generates all kinds of disease vectors, such as flies, rats, mosquitoes, dogs, cats and mice, and when they putrefy, they give off nauseating odours that make the population uncomfortable [9]. The problem of managing the Kalamu River in its urban section is therefore acute, endangering human health and the environment. To deal with this situation, it is essential to have effective legal instruments to organise the distribution and control of the use of water resources and to ensure their protection and conservation.

The new approach of Integrated Water Resources Management (IWRM) through the 'River Contract' may be a solution to the problem of the Kalamu river, because it has already shown its effectiveness in Africa, particularly in the

Lukaya river catchment in the DRC and in the Sourou river in Burkina Faso [9]. The river contract is a technical instrument for Integrated Water Resources Management (IWRM), this IWRM approach being considered as a new paradigm for water operators in the river basin and sub-basin [1].

Thanks to the river contract, public and private partners brought together within a river user structure define, by consensus and on a voluntary basis, an action programme with a view to restoring the multiple functions and uses of water on a catchment scale [1]. Our intention was clarified at the first international symposium on water issues in the Democratic Republic of Congo in Kinshasa [1]. It was in 2007, when the first international symposium on water was organised in the provincial city of Kinshasa, that the river contract was presented for the first time by Dr Rosillon's team from the University of Liège (Belgium). One of the topics discussed at the conference was the introduction of a system of integrated water resource management (IWRM) in the Democratic Republic of Congo [10]. This gave rise to the idea of exporting the Walloon model of river contracts and applying it to the Lukaya river as a pilot project for the Democratic Republic of Congo.

To alleviate this situation, we propose drawing inspiration from the experiences of the Rosillon river contracts [11], [2], [12], [1], [13] in Wallonia and the Semois region of Belgium, as well as those of the Sourou in Burkina Faso and the Lukaya in the Democratic Republic of the Congo. These initiatives are not models that can be directly replicated in Boma, but rather points of reference whose principles can be adapted to local circumstances, taking into account institutional, legal, financial and socio-economic differences, notably the lack of resources, weak enforcement of regulations and limited institutional capacity.

In this context, the principles of stakeholder participation, consultation, shared responsibility and the setting of common objectives remain relevant. The experiences in Lukaya and Sourou are particularly useful due to their proximity to the realities of countries in the Global South. They provide lessons on stakeholder mobilisation and participatory water governance, though they do not constitute evidence of sustainable success or automatic transferability.

Their scope depends, in particular, on the duration of the schemes, the commitment of the stakeholders, the resources available and institutional capacities. In Boma, a gradual and context-specific approach therefore appears more realistic. It could involve mobilising stakeholders, identifying priority issues and defining coordinated actions in line with available resources. The Kalamu River Contract will also need to incorporate the ecological, social, economic and heritage dimensions of the catchment, in accordance with the guidelines of the 2015 Water Act. The aim of this research is therefore to assess the relevance of, and the conditions for adapting, a river contract in the Kalamu catchment area in Boma. The focus is on identifying transferable principles and the adjustments required to suit the local context, rather than directly replicating a model developed in Belgium.

2. Study area

2.1. Localisation

Several descriptions of the Kalamu River catchment at Boma have been carried out, including by Vuni et al., ([14], [8], [7], [5], [9]), Masiala et al., [15] and Wanga et al., [16], [17]. The present study focused on 10 km of the Kalamu river, which has a total length of 63.131 km. Its catchment covers an area of 68.84 km² and its perimeter extends over 44.36 km (Figure 1). It springs from the Malanda Nsimba massif, located in the Lunga Vassa group at an altitude of 300 m, and empties into the plains of the Congo River at an altitude of 181 m, near the seaport of Boma. Along its course, the river flows through several villages: Kimbenza, Kiaku, Kikudu, and bathes the communes of Kalamu, Kabondo and Nzadi in the town of Boma.

Located between 13° 00' 00'' and 13° 11' 30'' E longitude and 5° 39' 00'' and 5° 51' 00'' S latitude. Boma's vegetation consists of man-made wooded savannah and gallery forests. In addition, this geographical area is open to south-westerly winds influenced by the cold Benguela marine current, and experiences two well-contrasting seasons of the wet tropical Aw₄ type according to Köppen's classification. The rainy season lasts 8 months from october to may. Rainfall varies between 900 and 1,500 mm, with a slight dip between mid-January and mid-March. The dry season runs from mid-may to september, with virtually no rainfall. The average annual temperature is 25°C. There is a low level of sunshine, ranging from 20% to 60% between 7 a.m. and 5 p.m.

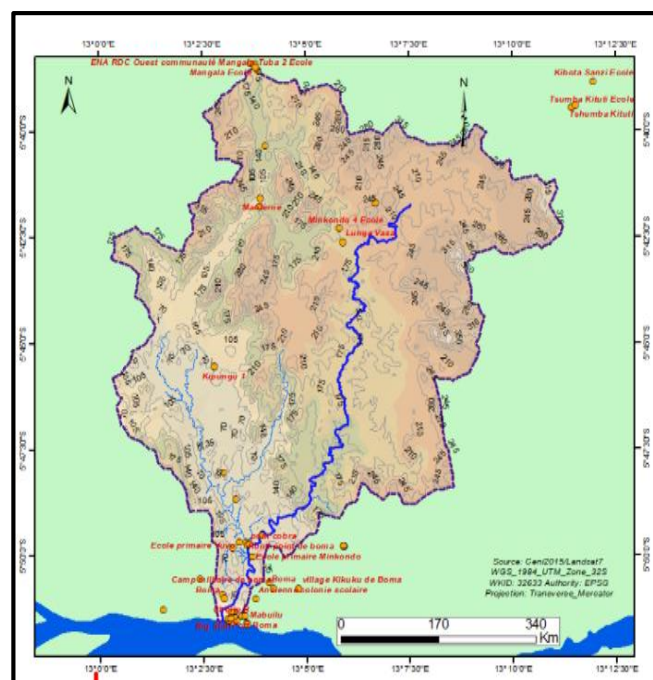


Figure 1. Map of the Kalamu River catchment area at Boma.

2.2. Methodological approach

This study was carried out using desk research and fieldwork, surveys, direct observations, interviews and photography. Data collection in the field was carried out through surveys, questionnaires and semi-structured

interviews with key stakeholders. The study population consisted of 378,681 households. The sample size was determined using the Bernoulli–Cochran formula, adjusted for a finite population:

$$n = \frac{Z^2 p(1-p)N}{Z^2 p(1-p) + e^2(N-1)}$$

Where n represents the sample size, N the total population, Z the value corresponding to the confidence level, p the estimated proportion of the characteristic under study, 1–p its complementary proportion, and e the acceptable margin of error. For this study, the parameters used were N=378,681, Z=1.96 for a 95 per cent confidence level, p=0.5, q=0.5 and e=0.05. The calculation yields a sample size of 383.77, rounded to 384 households. Consequently, the survey covered 384 households. Samples were taken all along the river, from Intu-popi to the outlet, making a total of 9 samples. The nine sampling points were selected on the basis of prior knowledge of the terrain and their representativeness of the main activities and potential sources of pressure on the catchment area. The sites were distributed to cover different sections of the watercourse, notably areas subject to domestic, agricultural and other human activities, as well as upstream and downstream sections.

This selection aimed to characterise the spatial variations in the physico-chemical and microbiological parameters under study. Sampling was carried out at specific points at the nine sites on 20 July 2024 for the dry season and on 15 December 2024 for the wet season. For quality assurance and control, measurements of pH, conductivity and TDS were taken using instruments that had been previously calibrated off-site.

The 9 sites were selected on the basis of the following criteria: (1) Location within the catchment area: to cover different sections of the river, from upstream to downstream, (2) Impact of human activities: proximity to homes, markets, agricultural areas, craft industries and other riverside activities, (3) Potential presence of discharges: domestic wastewater, waste, surface runoff and other inputs likely to affect water quality, (4) Water uses: areas where the local population makes direct use of the river for various activities, (5) Accessibility and safety: the ability to reach the site regularly and take samples under acceptable conditions, (6) Spatial representativeness: avoid concentrating all 9 points in a single section of the river, (7) Comparison of areas: include areas that are relatively less affected by human activities and areas that are heavily impacted by human activity. The main sampling sites were as follows: Intu-popi, Mbangu, Kifua, Sindi, Kabondo, Pont ville, Sinai, first basin and outlet. At each sampling point, the geographical coordinates (longitude, latitude) were measured using a Garmin 64 st GPS. After sampling, the bottles were kept in a tray filled with ice. The samples were stored in identified plastic bottles that had been sterilised beforehand, sterilised beforehand. The bottles were then stored in a refrigerator at a temperature of 4°C. Other parameters underwent physico-chemical tests using appropriate equipment:

- WTW pH 330 meter (accuracy 0.01 pH unit), WTW 315i conductivity meter (accuracy ± 1 digit), and TDS meter.
- The information collected was entered, processed and analysed using computer software: EpiData 3.0 for data encoding and entry. Microsoft Excel 2016 and SPSS 22 for flat sorting, cross-sorting and inferential analysis. ArcGIS 10.8 for map design.

Figure 2 refers to two tried and tested approaches for implementing a Sourou river contract in Burkina Faso in 2007 and the one established in the Walloon region in 2007 by the Rosillon team. It enables a participatory inventory to be drawn up and objectives to be defined and implemented via an action programme. Figure 2 - Methodological framework for the implementation of a contract for the Kalamu River in Boma modified in accordance with Rosillon 2007.

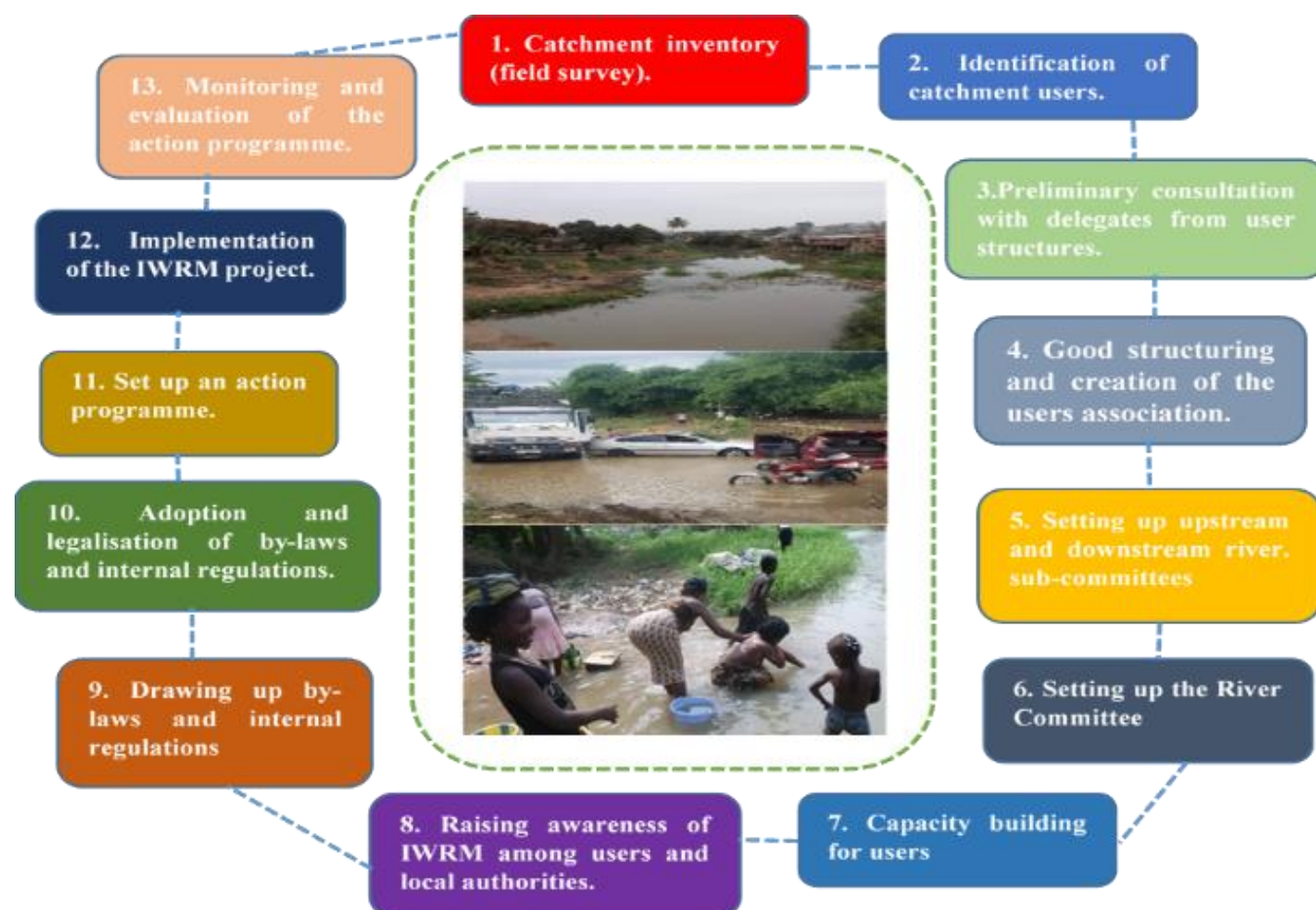


Figure 2. Methodological framework for the implementation of a contract for the Kalamu River in Boma modified in accordance with Rosillon 2007.

2.3. Involvement and awareness-raising amongst stakeholders regarding the participatory approach

A total of 82 participants attended the workshop on the Kalamu River Contract in Boma. Participants were selected on the basis of their role in land management, their involvement in activities relating to the catchment area, and their interest in water resource management. Political and administrative authorities, technical departments, civil society organisations, community stakeholders and the river's main users were thus involved in the workshop.

The participants included, in particular, 1 head of an urban division, 3 mayors, 17 neighbourhood leaders, 1 urban agriculture inspector, 1 head of the social affairs office, one head of the public works office, one head of the urban planning and housing division, one head of the urban environment division, one head of the spatial planning office, one head of the land registry division, one head of

the home affairs office, one coordinator from the Roads and Drainage Office and one representative of the provincial governor. The health and education sectors were also represented by 4 doctors and 4 headteachers.

Religious communities were represented by 4 pastors. Civil society included, in particular, 1 coordinator from PADERU/ASBL, 2 representatives from the Pro-Congo Foundation, 1 representative from the Association of Women with Disabilities for Integrated Development and 3 representatives from the Ntoto Association.

The workshop, which took place from 10.30 am to 3.00 pm, saw a high level of engagement from participants. They painted a worrying picture of the state of the River Kalamu, in relation to their respective sectoral activities. Among the issues raised were water pollution, inadequate management of buffer zones, bank erosion, silting, disruption to the riverbed, deforestation, the decline in biodiversity and recurrent flooding. Although the discussions were particularly lively and the participants expressed a desire to

analyse the systemic causes of these issues in greater depth, the scope of this session was strictly limited to an initial introduction to the participatory approach to water resource management.

This initial objective was fully achieved, with the stakeholders reaching a consensus on several areas for action, foremost among which were raising awareness and strengthening consultation (figure 3). All participants

expressed a desire to repeat these discussions and voted in favour of setting up a river committee. The river contract is a participatory tool for water resource management. Its success depends on raising awareness amongst stakeholders from various sectors and levels of responsibility. This approach is structured around two key areas: assessing the potential for participation and providing information to users, who will be the project's future stakeholders.



Figure 3. Photo of the workshop

3. Results and discussion

3.1. Results

3.1.1. Procedure for implementing a river contract

The identification and analysis of public, private and civil society stakeholders are essential at every stage of the study in order to ensure its reliability. These stakeholders, through their powers and influence, play a decisive role in the design, planning and implementation of the river contract. A classification into three categories, based on their

importance and level of involvement, is presented in the attached figure (figure 4). The project will begin with an in-depth scoping phase, aimed at aligning understanding of the issues and objectives, as well as defining an operational action plan. A kick-off meeting will be organised to confirm a thorough understanding of the specific features of the river contract and the chosen methodology, followed by a comprehensive literature review.

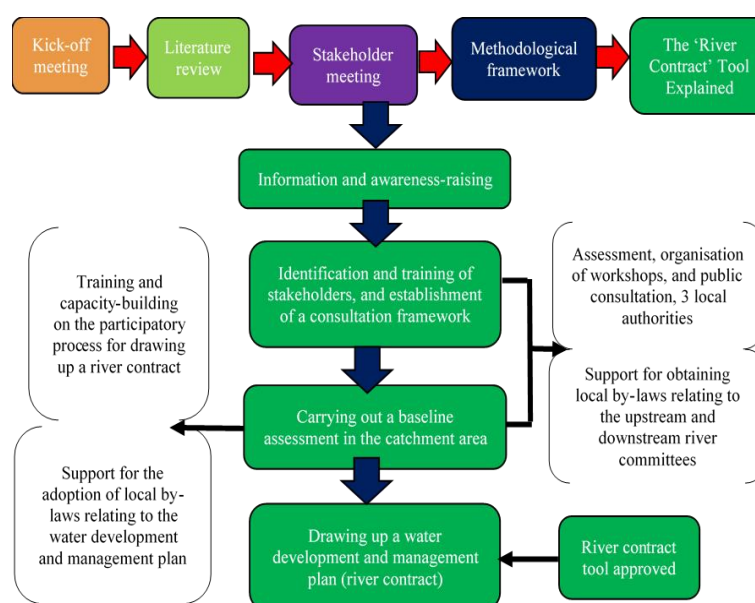


Figure 4. Procedure for implementing a river contract.

3.1.2. Waste management

Waste management is still a serious problem in the town of Boma. Solid waste can be seen all along the arteries and crossroads. Figure 5 shows how waste is disposed of in this town. Out of a total of 384 households surveyed, 43% dumped their waste in rivers, 12% deposited it in the street, 11% composted it, 10% incinerated it on site, 9% deposited it in gutters, 8% buried it on site and 7% deposited it in fields (figures 5 and 6).

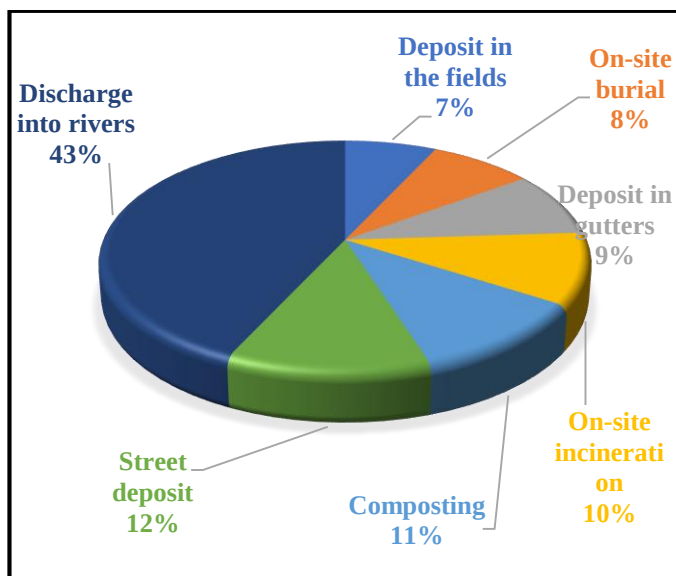


Figure 5. Waste disposal methods.



Figure 6. Presence of solid waste along the river.

3.1.3. Causes of deforestation

The main causes of deforestation in the Boma catchment area of the Kalamu river are house building (31%), slash-and-burn agriculture (19%), timber production (14%), wood for cooking bricks and bread (13%), illegal logging (12%) and bush fires (11%) (figure 7).

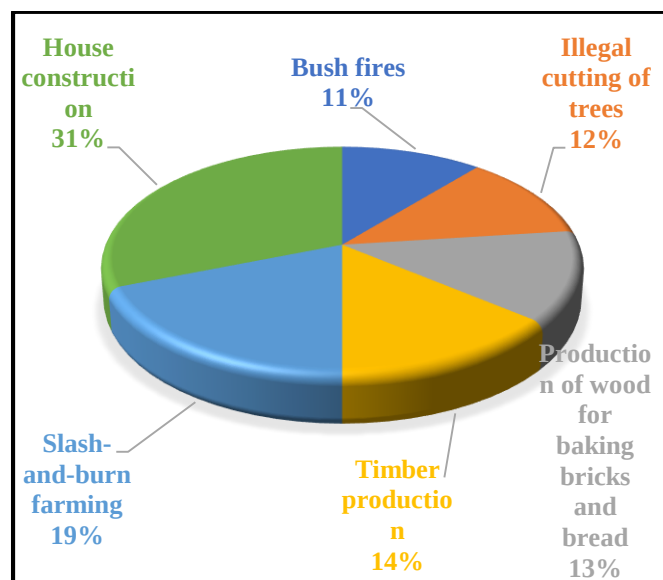


Figure 7. Causes of deforestation.

3.1.4. Origin of flooding in the catchment area

Figure 8, shows that out of a total of 384 respondents, 16% were in favour of uncontrolled construction, 15% said that deforestation was the cause of flooding, 14% thought that it was the lack of maintenance of the river, 13% considered the lack of maintenance of gutters, 12% the inadequacy of the sewer system, 11% pointed to silting in the river, 10% said that uncontrolled dumping of waste in the river and 9% climate change (figures 8 et 9).

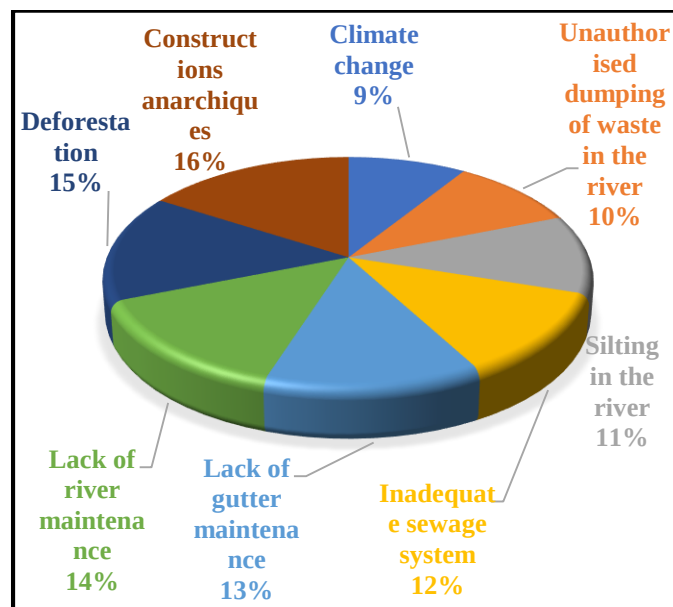


Figure 8. Origin of flooding in the catchment area.



Figure 9. House flooded by the waters of the Kalamu river.

network, insufficient financial and material resources, low user involvement, and a lack of coordination. These results show that, in addition to infrastructure, watershed management requires better governance and coordination among stakeholders. With this in mind, a move toward a river contract could be based on stakeholder engagement, a shared assessment, the definition of a program of priority actions, and a monitoring and evaluation mechanism. Funding for these initiatives could be based on a diversified mobilization of resources, involving public authorities, technical and financial partners, NGOs, and, where possible, economic actors and users. Governance, for its part, should promote a consultative structure bringing together city hall, technical departments, users, community organizations, and relevant partners. This approach has the potential to be replicated in other urban or peri-urban watersheds facing similar problems. However, its implementation will need to be adapted to the institutional, socioeconomic, hydrological, and environmental context of each region.

3.1.5. SWOT Analysis

The SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats) helps identify the main strengths and constraints of the Kalamu River watershed and guide management actions (Table 1). It highlights local capabilities including awareness among authorities, the availability of human resources, the existence of an environmental department and a regulatory framework as well as weaknesses related to the dilapidated drainage

Table 1. SWOT Analysis of the Kalamu River Watershed in Boma.

Strengths	Weaknesses
- Awareness of the issues at the town hall level; - Availability of young human resources - Existence of the Forest Code, the Water Code, and fundamental environmental principles - Constructive relationships among certain users - Soil fertility - Accessibility of the town and the watershed; - Availability of water resources; - Organization of a weekly sanitation day; - Existence of an environmental and sanitation department.	- Deterioration of the drainage system - Lack of river maintenance - Lack of water quality monitoring - Failure to enforce laws and regulations - Lack of a common waste management policy - Landscape fragmentation due to urbanization; - Lack of a formal user organization - Insufficient financial and material resources - Low public awareness of sanitation - Insufficient public trash cans and landfill sites - Low user involvement - Sediment buildup in the river

Opportunities	Threats
- Commitment from local authorities; - Presence of environmental NGOs; - Implementation of a river management agreement; - Ability to secure funding; - Development of institutional partnerships; - Strengthening user participation; - Rehabilitation of drainage infrastructure; - Development of agriculture, fishing, and livestock farming; - Tourism potential linked to the river, the port, and the ocean; - Development of integrated water resources management	- Ongoing population pressure; - Significant urban development pressure; - Poor land use; - Degradation of vegetation cover; - River pollution; - Illegal dumping of waste; - Recurring floods; - Erosion of riverbanks; - Loss of biodiversity and degradation of ecosystems; - Potential impacts of climate change

3.1.6. Analysis of surface water quality

Analysis of surface water quality is based on the measurement of physico-chemical parameters and the presence or absence of aquatic organisms and micro-organisms, which are indicators of the quality of the water. Taken together, these elements make it possible to assess the degree of pollution in watercourses and their ability to purify themselves.

3.1.7. Results of microbiological analyses

Table 3 presents the results of microbiological analyses carried out on water samples taken from the Kalamu River in Boma during the dry and wet seasons. The assessment focuses on three indicators of faecal contamination:

Escherichia coli, total coliforms and enterococci, expressed in colony-forming units per 100 ml (CFU/100 ml). The data collected reveal a significant deterioration in the sanitary quality of this water resource. The detection of *Escherichia coli* is a key indicator of sanitary quality. As it is closely associated with human and animal faeces, this bacterium is recognised as a reliable marker of recent faecal contamination. The World Health Organisation recommends the use of *E. coli* as a reference microbiological indicator for the assessment of water intended for human consumption. In accordance with current standards, no 100 ml sample of drinking water should contain any detectable traces of this bacterium.

Tableau 3. Results of microbiological analyses

Sampling points	<i>Escherichia coli</i> (CFU/100 ml)	Total coliforms (CFU/100 ml)	<i>Enterococcus</i> (CFU/100 ml)
Kalamu (Intu popi)	2160	More than 4,000 colonies	1400
Kalamu (Sinai)	470	More than 4,000 colonies	3000
Kalamu (1 ^{er} bassin)	420	More than 4,000 colonies	5700
Kalamu (pont ville)	1600	More than 4,000 colonies	1500
Kalamu (Exutoire)	600	More than 4,000 colonies	1480
Sindi	300	More than 4,000 colonies	1800
Kifua	2160	More than 4,000 colonies	1120
Mbangu	510	More than 4,000 colonies	1600
Kabondo	3200	More than 4,000 colonies	1000
WHO guidelines (2011)	Not present in 100 ml of water	Not present in 100 ml of water	Not present in 100 ml of water

Table 2 presents the results of the physico-chemical analysis of the water in the Kalamu River at Boma for the 9 sampling sites.

Table 2. Physico-chemical parameters

Sampling sites	pH	Conductivity $\mu\text{S/cm}$	TDS mg/L
Intu popi	7.51	89	44
Mbangu	7.18	259	129
Kifua	7.27	186	93
Sindi	7.42	190	95
Kabondo	7.69	781	39
Pont ville	7.21	574	286
Sinaï	7.23	101	50
1 ^{er} bassin	7.37	171	85
Exutoire	7.14	165	82
WHO standards	6.5 - 9.5		≤ 300 ppm

3.1.8. Problem tree in the development of a Kalamu river contract in Boma

The problem tree is a methodological tool used to draw up a river contract, providing a diagram to help analyse a problematic situation in a catchment area. It is a means of preventing similar accidents from happening in the future, and also helps to better identify the risks and their causes, so that action can then be taken to eliminate or minimise them if possible (figure 10).

3.1.9. Solution tree in the development of a Kalamu river contract in Boma

The solution tree is the positive mirror image of the problem tree. You have to start at the roots of the tree: for each cause, starting with the deepest, find a potential solution (figure 11).

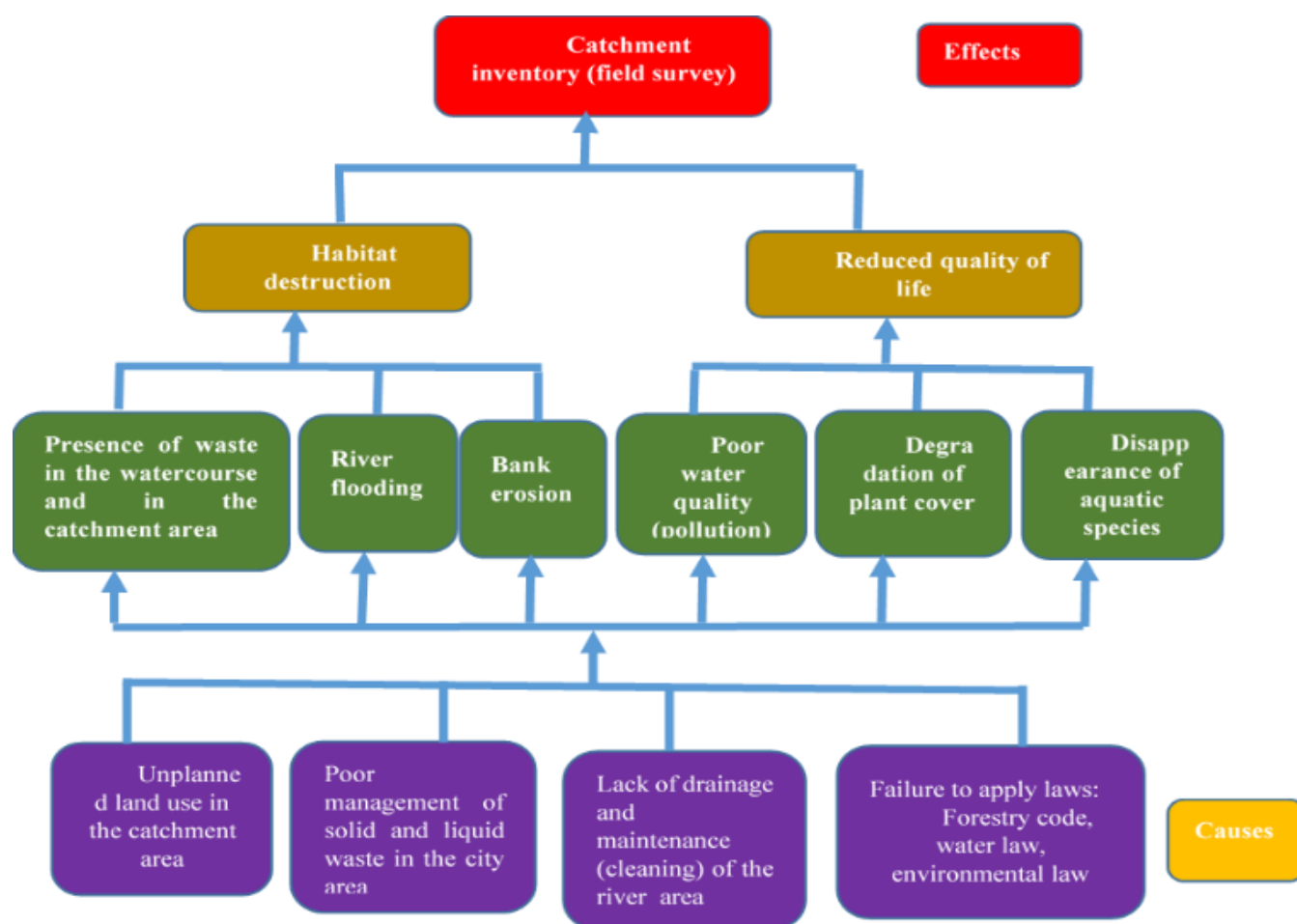


Figure 10. Problem tree in the development of a Kalamu river contract in Boma.

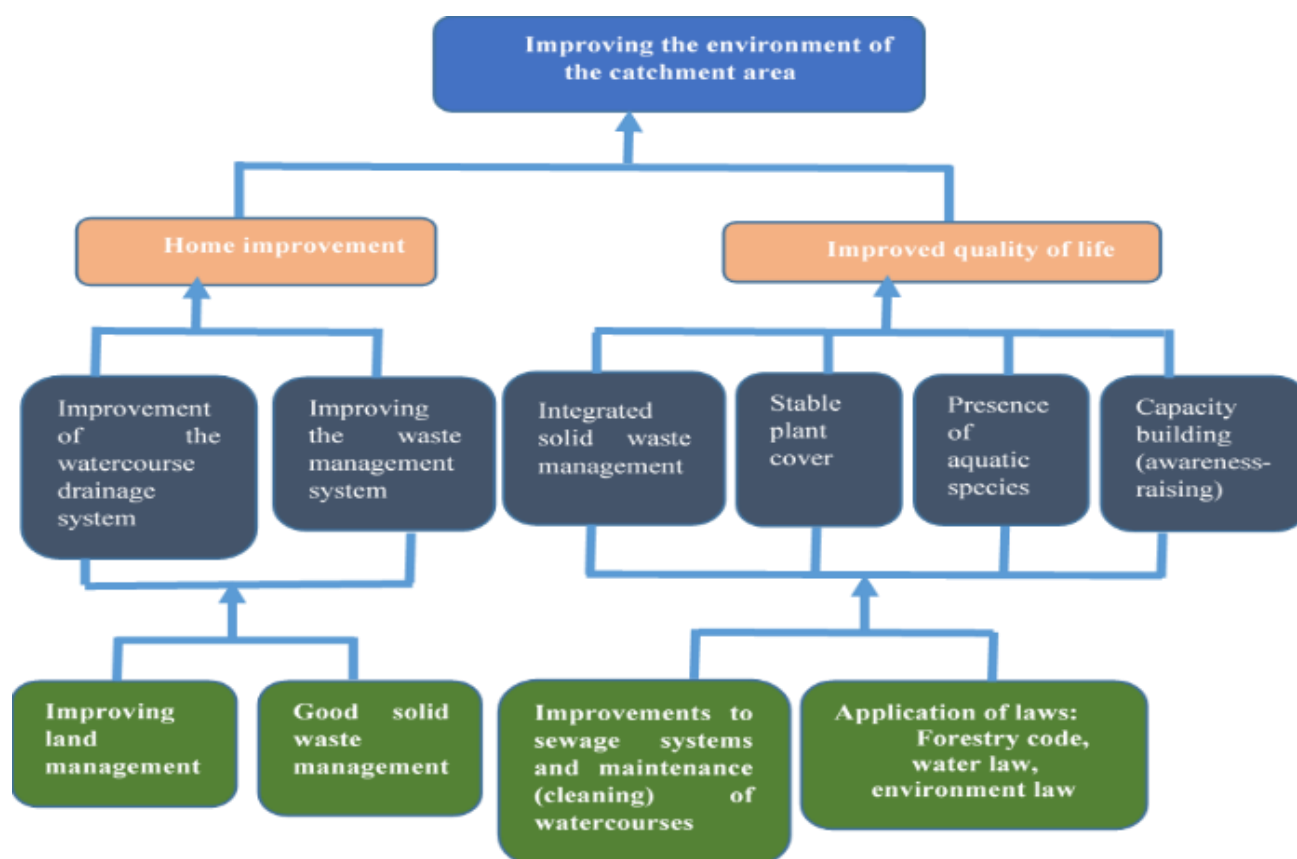


Figure 11. Solution tree in the development of a Kalamu river contract in Boma.

3.1.10. Establishment of a river committee

To set up a river committee, each organisation operating within the catchment area must appoint members (focal points) to the river committee (upstream and downstream). These focal points, acting as technical and institutional representatives, will ensure the consistency of activities and sector-specific data, their validation, and their integration into the sustainable development and management plan for the Kalamu river catchment area in Boma (figure 12).

Their involvement from the outset of the river contract project will facilitate the implementation of an action programme. Finally, the success of a river committee depends on strong local support extending beyond the town hall. Their active participation will ensure local legitimacy

and the transfer of skills, the joint validation of data, and the effectiveness of the river committee.

This framework ensures that the sustainable development and management plan for the Kalamu River catchment in Boma is not merely a technical document, but a genuine tool shared and utilised by local stakeholders in line with the principles of a river contract.

This approach guarantees social inclusion, respect for free and informed consent, and the incorporation of local knowledge into the formulation and guidelines of a sustainable development and management plan for the Kalamu River catchment area in Boma.

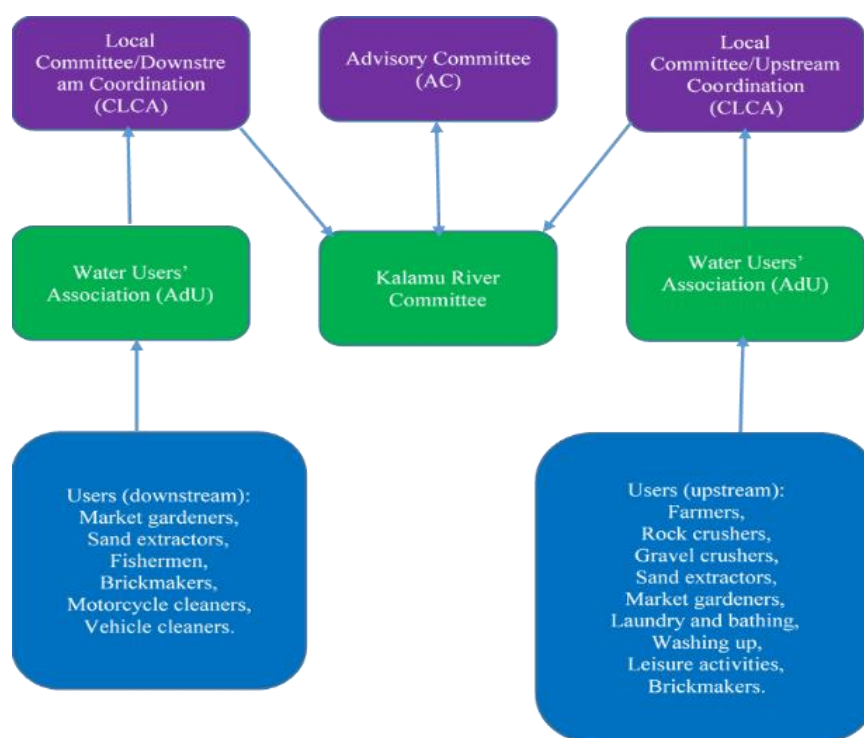


Figure 12. Establishment of a river committee.

Table 4. Explains some of the factors to be taken into account when drawing up a programme of action in response to the problems identified above

Issues	Problems	Planned activities	Expected results
Water	Pollution	Promoting sanitation techniques (pollution control) and monitoring water quality	A healthier aquatic ecosystem
	Flooding	Set up an early warning system (EWS)	SAP installed and operational (population notified in advance)
	Lack of cleaning	Cleaning the river	Maintained river
	Lack of an IWRM awareness programme	Set up an IWRM awareness-raising programme for stakeholders	Operational awareness programme
	No hydrometeorological equipment	Installing hydrometeorological equipment	Hydrometeorological observation station set up and operational (hydrometeorological data available)
GROUND (Environment)	Erosions	Promote the construction and maintenance of roadworks (civil engineering) and anti-erosion measures using plant engineering.	Anti-erosion structure and roadway installed and soil stabilised
	Deforestation	Setting up agroforestry systems for reforestation	Agroforestry system set up (areas will be reforested)
	Urban sprawl	Drawing up land use maps	Land use maps available
	Lack of an awareness programme	Set up a programme to raise awareness among stakeholders	Operational awareness programme
	Poor waste management	Set up a waste treatment programme	Sanitation programme in place and operational

3.2. Discussion

The Integrated Management of the Kalamu River in Boma is an initiative that is part of the 2015 water law. The initiative aims to restore the river and its catchment area, reducing the risks associated with flooding [18]. Restoring rivers and their catchment areas is a practice that aims to rehabilitate their ecological functions with a view to improving ecological quality but also increasingly targeting other interests, particularly socio-economic [19]. [10] prefers to talk about the adaptability of a river contract in the Lukaya catchment area in the Democratic Republic of Congo.

From the results obtained, they were able to observe that heavy industrial and artisanal mining activity has a negative impact on the physical environment and water quality. Overall, water quality was judged to be fairly good in terms of organic pollution. However, they identified a major problem of organic contamination linked to the discharge of wastewater directly into a tributary of the river by a poultry farm.

The forest in the Kalamu river catchment area has clearly suffered from human pressures that are degrading it. [5] identified other causes of deforestation in the Kalamu river catchment at Boma: uncontrolled construction (31%), slash-and-burn agriculture (19%), firewood production (14%), adobe brick burning (13%), illegal timber cutting (12%) and forest fires in areas cleared for seasonal crops (11%). On this subject, [20] have calculated that the production of 1.65 bags of 45 kg per month per stère of 67 kg of charcoal comes from cutting 119.29 m² of forest per month, and that 98% of households in Boma cook with charcoal using artisanal charcoal-burning stoves [21].

Values of the same order of magnitude are reported elsewhere, such as in Kinshasa, 95% [22]. Furthermore, the total timber sold in Boma in 2013, 2014 and 2016 was estimated at 1,484.6, 1,533.16 and 1,399.4 m³ respectively [23]. Studies carried out at catchment scale have shown that erosion generally decreases when vegetation cover increases [2]. Similar results have been obtained for smaller areas, such as a few acres on a slope. Vegetation cover helps to stabilise the soil along river banks and regulate flooding [24] show that the Alexandra River (Alberta, Canada) is particularly stable due to the presence of plant cover.

The causes of flooding in the Kalamu river catchment area in Boma: the results of the study carried out by Vuni [7] are revealing. 16% are in favour of anarchic construction, 15% say deforestation, 14% think the lack of maintenance of the river, 13% consider the lack of maintenance of the gutters, 12% say the sewer system, 11% the silting up of the river, 10% the dumping of waste in the river.

Other studies [25] explain the causes of flooding in Kinshasa as follows: 50% silting up of the river, 36.36% presence of waste in the river, 31.82% uncontrolled construction, 27.27% lack of gutter maintenance. The study carried out by [26] on the causes of flooding in Tshopo province found that 80% was due to rain, 60% to overflowing river water, 40% to construction on marshy land, and 30% to a lack of gutter maintenance. The

consequences of flooding are varied in Senegal. They are economic, social and health-related. In economic terms, the sectors most affected include housing, industry, trade, transport and education.

According to GFDRR [27], the sectors most affected by financial losses include trade, particularly informal, with a proportion of 23%, followed by housing (18%), urban community infrastructure (18%), energy (17%) and transport (16%). The results of the study by [7] explain how waste is disposed of in the town of Boma: 43% dump it in rivers, 12% deposit it in the street, 11% compost it, 10% incinerate it on site, 9% deposit it in gutters, 8% bury it on site, and 7% deposit it in fields.

These results are similar to those of [26] on waste management in the Kalamu river and its tributaries: 81.3% of the plots in Boma throw their rubbish either into the torrents or into the river; The results are similar to those of [28], on how waste is disposed of in Kinshasa: 14.7% collected, 6.68% landfilled, 10.95% dumped, 7.28% dumped in a river, 6.6% composted, 10.35% collected, 14.78% dumped everywhere, 9.83% incinerated, 18.83% collected by NGOs. [27], explains how household waste is managed in Kikwit: 17.2% buried, 22% incinerated, 18.8% spread in avenues, 18% dumped in gullies, 8% dumped in streams, 4% dumped in gutters, 12% piled up on corners, 8% dumped in retention basins.

The account highlights the high vulnerability of households to flooding in the Kalamu River catchment area in Boma. The event of 10 December 2025 caused significant material losses and temporary displacement. The lack of assistance reveals the limitations of local disaster management. The fact that households remain in the area is mainly due to a lack of financial resources and rehousing options. The willingness of some flood victims to leave the area, with support from the State, highlights the importance of appropriate measures relating to prevention, rehousing and compensation in order to reduce flood-related risks in the long term.

The pH fluctuated between 7.14 and 7.69, the conductivity between 89 and 781 µS/cm and the TDS between 39 and 286 mg/L. The hydrogen potentials observed, with values between 7.14 and 7.69, comply with the standards recommended by the WHO (6.5 < pH < 9.5). These values are similar to those reported for surface waters, ranging from 6.5 to 9.5 (Masamba and [30]).

They are comparable to those found by [29] on the Meghna ghat river (Bangladesh). These values also correspond to those found on other rivers that flow through areas of high human activity [31]. Authors such as [32], [33], [34] confirm that high electrical conductivity also reflects the level of mineralisation of the water. This mineralisation depends on the solubility of dissolved and dissociated compounds, which indicates a high ion concentration.

According to [10], low electrical conductivity in a watercourse is also a sign of low mineralisation of salts present in the environment. Therefore, during the rainy season, it is reduced due to the dilution of salts and ions caused by precipitation. Water is delivered to homes through a cast-iron pipe network that is perforated in places

because it is too old. According to [16], the results of the physico-chemical parameters of the water in the Kalamu river in Boma in each sampling point are different, turbidity is linked to anthropogenic activities, the pH of the raw water varies from 6.6-8.5 the electrical conductivity varies between 50 and 1500 $\mu\text{m}/\text{cm}$, the colour is (93.83 Pt Co/l), the temperature (29.95°C), the electrical conductivity (72.42 $\mu\text{s}/\text{cm}$), turbidity (48.33 NTU), TDS (46.4 mg/l), suspended solids (45.5mg/l), dissolved oxygen (6.47mg/l), O_2 saturation (84%), NH_4^{4+} (0.16mg/l), Ca^{2+} (214 mg/l), Mg^{2+} (106, 11mg/l), Pb^{2+} (70.41 mg/l), Cd^{2+} (20.49 mg/l), Cl^- (58.9mg/l), Al^{3+} (3.03mg/l), BOD5 (18.5 mg O_2/l), COD (61.04 mg/l), PO_4^{3-} (76.28mg/l), NO_3^- (111.44mg/l) and SO_4^{2-} (7.61mg/l) [17].

4. Conclusion and recommendations

Following this study, the move towards a river contract in the Kalamu catchment area in Boma appears to be appropriate and feasible, provided that governance, institutional coordination and financial resources are strengthened. The assessment highlights a catchment area subject to significant human pressures, notably pollution, poor waste management, urbanisation, bank erosion, siltation and flooding. The results of the survey of 384 households confirm the scale of these problems. 43 % of households report disposing of their waste in rivers, 12 per cent on the streets and 9 per cent in drains. These practices highlight the shortcomings of the waste management system and constitute a major source of watercourse pollution. Households also identify unregulated construction (16 %), deforestation (15 %), a lack of river maintenance (14 %) and inadequate maintenance of drains (13 %) as among the main causes of flooding.

Water quality analyses reveal a mixed picture: the physico-chemical parameters remain generally acceptable for certain uses, whilst microbiological contamination poses a health risk for direct consumption. These results highlight the need for regular monitoring of water quality and for measures to reduce sources of pollution. The participatory workshop, attended by 82 stakeholders, demonstrated local interest in a collaborative approach to river management. The commitment of the authorities, the existence of a regulatory framework and the availability of technical services are significant assets for the establishment of a river committee.

The SWOT analysis enables the identified constraints to be linked to priority actions: drainage rehabilitation, river dredging and maintenance, improved waste management,

riverbank restoration, water quality monitoring and raising public awareness. The creation of a permanent consultation framework will enable these interventions to be coordinated. The success of the river contract will, however, depend on inclusive governance, bringing together authorities, technical services, users, communities, civil society organisations, and technical and financial partners. Funding will need to be diversified to ensure the gradual implementation of priority actions. For the Kalamu, the river contract serves as an operational tool for governance, resource mobilisation and the coordination of environmental actions. This experience could be adapted to other urban and peri-urban catchment areas in the DRC facing similar problems.

4.1. Operational recommendations

In light of the results obtained, the main challenges facing the Kalamu catchment area relate in particular to pollution and water quality, waste management, flooding, bank erosion, siltation, urbanisation, ecosystem degradation, as well as governance and stakeholder participation. The operational recommendations set out below therefore aim to strengthen the feasibility, adaptability and phased implementation of a river contract in Boma (tableau 5)

Tableau 5. Operational recommendations

Findings from the SWOT analysis	Proposed priority actions
Population pressure and urbanisation	Strengthening land-use planning and the protection of sensitive areas
Ageing drainage network + urban development pressure	To refurbish and maintain the drainage network
Lack of maintenance + build-up of sediment	Organise the dredging and regular maintenance of the river
Insufficient rubbish bins + fly-tipping	Set up collection points and improve waste management
Lack of water quality monitoring	Establish a regular programme to monitor water quality
Bank erosion + degradation of vegetation cover	Restoring and protecting riverbanks and riparian areas
Low levels of awareness and engagement amongst users	Raising awareness and encouraging community involvement
Lack of a formal user structure	Establish a local consultation framework
Lack of financial resources	Diversify sources of funding and seek partnerships
Existence of a local council service + commitment from the authorities	Structuring a process leading to a river management agreement

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