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RESEARCH ARTICLE

CHALLENGES AND OPPORTUNITIES OF PROVISIONING ECOSYSTEM SERVICES WITHIN LOCAL COMMUNITIES ALONG THE DIBOMBE RIVER IN THE LITTORAL REGION, CAMEROON

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ABSTRACT

Rivers throughout human existence have provided essential provisioning services such as water, food, and livelihoods ecosystem services for human survival and wellbeing of local communities. However, these services particularly in many communities of developing countries continue to face numerous environmental challenges due to current global development. By offering diverse benefits, a socioecological systems' output of rivers has the potential to provide a variety of goods and services that people use daily thus improving their living standards, wellbeing and health. Unfortunately, rapid degradation, deforestation, poor waste management, limited awareness and policy implementation have continued to limit the availability of human resource benefits, over harvesting and increase pollution. Using the context of Debombe River located along a rapidly developing industrial zone of Cameroon, this study aimed to (1) identify the patterns and use/benefits of ecosystem services, (2) assess the environmental challenges faced by communities, and (3) evaluate the socio-economic implications of these challenges. This study used a mixed-method approach, including surveys through questionnaire administration to 300 community members using a stratified and representative sampling method, interviews with results showed that over 78% of respondents who relied on river Dibombe for various livelihood opportunities faced although over 78% of the respondents rely heavily on the river for livelihoods, they face significant environmental challenges, including pollution, deforestation, and climate change, with socio-economic implications such as reduced income, food insecurity, and health risks due to land use changes and lack of policy implementations. The study highlighted the need for collaborative management approaches that balance human well-being with ecosystem conservation through the implementation of sustainable practices, strengthening conservation efforts, promoting community-based management and supporting climate change adaptation initiatives to ensure efficient and effective service provision for the wellbeing of the population.

KEYWORDS

Ecosystem provisioning services, environmental challenges, livelihood, community-based management, Dibombe River, Cameroon.

1. INTRODUCTION

Ecosystem services defined as the natural ecological processes that sustain and fulfill human life include provisioning services (products obtained from ecosystems, eg, food, freshwater, wood and fibre and fuel) (Millennium Ecosystem Assessment -MEA, 2005). In contrast, the global initiative "The Economics of Ecosystems and Biodiversity" (TEEB, 2010) to value biodiversity, considered provisioning services as products resulting one of these vital provisioning services human existence, have been cornerstones of human civilization, providing essential provisioning services that sustain life and livelihoods (Wang and He, 2022). It is worthy to note that freshwater provisioning services are not only limited to lakes and rivers, there are also known as riparian zones along river banks which provide woodland for firewood and edible plants (Freshwater Information System - FIS, 2025). These services encompass a wide array of benefits, including access to fresh water for drinking, agriculture, and domestic use; food sources such as fish and aquatic plants; and direct livelihood opportunities through fishing, farming on fertile floodplains, and transportation thus contributing to the socio-economic development, poverty alleviation and overall well-being of the population (Wang and He, 2022; OFB, 2025; Daily, 1997; MEA, 2005; OFB, 2025). However, despite their critical importance, these invaluable ecosystem provisioning services in many communities of developing countries are increasingly under threat. This view is supported by Luo et al. (2020) who noted a link between the natural world and human beings and that rivers were affected by climate change, human activities despite their potential benefits, and changes in water demands for instance have increasingly become the leading factors of high-intensity spatiotemporal variation of global rivers, thereby causing many problems related to water scarcity, pollution and increase demand that pose challenges to human survival, wellbeing and socioeconomic development (Luo et al., 2020 cited in Wang and He, 2022).

Current global development paradigms, often characterized by rapid urbanization, industrial expansion, and intensive resource exploitation, exert immense pressure on riverine ecosystems in many developing countries including those in Africa, Latin America and South East Asia

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(Raffaelli and White, 2013). This have often led to a decline in the systems' capacity to provide essential provisioning services like water, food and fibre, thereby jeopardizing the very communities that depend on them (MEA, 2005; World Water Assessment Programme, -WWAP, 2015; 2020). For instance, changes in population size or community composition of these service-providing units in response to anthropogenic activities often affect intermediate the immediate communities who depend on them and therefore also final ecosystem services (Raffaelli and White, 2013).

In fact, human impact has been identified as the main driver of changes in ecosystems and associated provisioning services in many African Countries (MEA, 2005). The degradation of coastal areas closes the ocean is manifested through various forms: rapid degradation of water quality, extensive flooding, deforestation of riparian zones, and poor waste management practices. These issues are frequently exacerbated by development priorities, and increase industrialization that overlook environmental safeguards, limited public awareness of ecological fragility, and insufficient policy implementation and enforcement (UNEP, 2016; WWF, 2020). The impacts of rapid urbanization and climate change on rivers are multifaceted. Firstly, climate change will affect the safety of river flood control (Zhang et al., 2015). Also increasing water demand is another critical challenge facing rivers (Carvalho et al., 2019). Despite its benefits for drinking, food and industries, over-abstraction of surface and groundwater can have negative impacts on ecosystem health and function, and cause lakes and rivers to become seasonally dry, with potentially negative impacts on human livelihoods, and reduce the provision of other ecosystem services. Water demand is largely influenced by population growth, urbanization, food and energy security policies, and macro-economic factors, such as trade globalization and changing consumption patterns. Global water use had increased six-fold over the past 10 decades; since the 1980s, global water use has continued to grow at a steady rate of 1%per year. Water scarcity has now become a wide spread and increasingly severe problem worldwide (WWAP, 2020) cited in (Wang and He 2022). Aquaculture can also have negative effects on the wider environment, through pollution from feed and waste and the genetic and behavioural impacts of escaped (sometimes non-native) fish on wild, breeding populations (FIS, 2025).

Consequently, information about effects of land-use change on service-providing units and associated ecosystem services is increasingly demanded by managers and policy makers in order to promote the sustainable use and continuous provision of services (e.g., by the conference of the parties to the convention on biological diversity; CBD, 2010). Given the negative environmental externalities of some intensive management strategies (e.g., groundwater pollution and resource depletion), alternative management strategies that integrate intermediate services by promoting service-providing units are an opportunity to sustainably ensure crop production and to reduce reliance on anthropogenic interventions (Bommarco et al., 2013).

Unfortunately, for Cameroon, like many other African nations where rivers are central to the livelihoods of a significant portion of the population, especially in rural and peri-urban areas, in the Littoral Region, burgeoning industrial zones characterized by rapid environmental changes, exemplifies this complex dynamic, where the push for economic growth often directly conflicts with environmental sustainability (ARCADIS, 2025). The Dibombe River, flowing through this rapidly developing industrial landscape, serves as a microcosm of these broader challenges, reflecting the global tension between human development needs and the imperative of ecosystem conservation. Understanding the state of its provisioning services, the challenges it faces, and the implications for its dependent communities is crucial for fostering truly sustainable development in the region.

Local communities along the Dibombe River in the Littoral Region of Cameroon rely heavily on its provisioning ecosystem services—such as water for domestic use, fish for food, and fertile land for agriculture—to sustain their livelihoods and well-being. Over 78% of the surveyed respondents depend significantly on the river for these essential services. Despite this critical dependence, the river's health and its capacity to provide these services are severely compromised. Communities face numerous environmental challenges, including widespread pollution from industrial and domestic waste, extensive deforestation along riparian zones, and the exacerbating effects of climate change. This environmental degradation is a direct consequence of rapid and often unregulated development priorities, inadequate waste management systems, limited public awareness regarding environmental stewardship, and significant gaps in the implementation and enforcement of environmental policies. The direct socio-economic implications of these challenges are profound and alarming. Communities experience reduced income due to dwindling fish stocks and compromised agricultural yields, heightened food insecurity as natural food sources decline, and increased health risks stemming from consuming polluted water and contaminated produce. These impacts are further intensified by rapid land-use changes that disrupt natural river processes and the persistent lack of effective environmental governance. Although stakeholders have made efforts through conservation initiatives and sustainable practices, these interventions are often fragmented and insufficient, primarily due to persistent limitations in awareness among local populations and a critical lack of financial resources. Consequently, the life-sustaining services provided by the Dibombe River are rapidly diminishing, threatening the very survival and well-being of the communities that have historically depended on it, leading to a precarious balance between human needs and ecological integrity that demands urgent scientific investigation and actionable solutions.

Despite the recognized importance of riverine ecosystem provisioning services in sustaining local communities in developing countries and the evident environmental degradation affecting MEA, 2025; WWAP, 2015, 2020; WWF, 2020 among others several gaps remain in the specific context of the Dibombe River and similar rapidly industrializing regions of Cameroon. Existing literature often generalizes diverse benefits of provisioning ecosystem services derived without detailing how different segments of the population utilize various services, which is crucial for targeted management interventions. There are limited empirical data quantifying the specific extent and nature of environmental challenges along the Dibombe River and most studies focus broadly on urban pollution or deforestation without specifically linking them to the degradation of riverine ecosystem services and their direct impacts on provisioning capacities in this specific geographical setting. Also, there is limited assessment linking environmental challenges along the Dibombe River directly to tangible socio-economic consequences such as quantified income reduction, precise indicators of food insecurity, and the prevalence of specific health risks within the local communities. Hence, understanding these gaps and the direct linkages between these variables is vital for illustrating the human cost of environmental degradation. This study aims to bridge these gaps by providing localized, empirical data and a multi-faceted analysis to inform sustainable management strategies for the Dibombe River's ecosystem services.

This study holds significant importance as it specifically provide a clearer understanding of the threats to community primary source of livelihood and well-being thus empowering them with knowledge about the specific environmental challenges and their socio-economic implications. This could foster greater awareness and promoting active participation in conservation efforts. In addition, data collected through this study can inform the development of more effective, localized, and enforceable environmental policies, waste management strategies, and land-use plans in Cameroon. This study also highlights the urgent need for integrated water resource management through well design conservation initiatives and community-based management programme and environmental and social costs assessment of industrial activities on crucial ecosystem services. These assessments could encourage the adoption of more responsible and sustainable industrial practices, promote corporate social responsibility (CSR) and mitigate negative externalities. This study will inform stakeholders on the important of addressing critical issues related to clean water and sanitation (WaSH) (SDG 6), sustainable cities and communities (SDG 11), responsible consumption and production (SDG 12), climate action (SDG 13), and life on land (SDG 15), thus directly contributing towards the achievement the United Nations Sustainable Development Goals (SDGs) (UN, 2030) in Cameroon. Ultimately, this research seeks to facilitate a more balanced and sustainable relationship between human development and environmental conservation along the Dibombe River thus promoting long-term well-being for its dependent communities. To achieve all these, this study aimed to assess the challenges and opportunities of provisioning ecosystem services within local communities along the Dibombe River, Littoral Region, and Cameroon through identify the patterns and use/benefits of provisioning ecosystem services, assessing the environmental challenges faced by communities and their resultant the socio-economic implications.

2. Socio-Ecological System (SES) Framework (Ostrom, 2009)

In 2009, Elinor Ostrom (winner of the Nobel Prize) introduced the SES framework based on decades of Ostrom's empirical work on the commons. The framework provides guidance on how to assess the social and ecological dimensions that contribute to sustainable resource use and management across scales and contexts. The research on provisioning ecosystem services along the Dibombe River is fundamentally rooted in

the conceptual framework of a SES. This interdisciplinary concept recognizes the inherent interconnectedness and co-evolution of human (social) and natural (ecological) components, emphasizing that neither can be fully understood in isolation. A SES is defined as a coherent system of biophysical and social factors that regularly interact in a resilient, sustained manner. SES can be described as a "system of people and nature". While this may seem intuitive, the close connection between people and nature has not always been central in environmental thinking (ESRC 2022).

According to the SES framework, the subsystems that make-up SESs can function independently, such as governance systems, users of a system, and the units produced by the system, but then join to produce complex social-ecological systems. When using fisheries as an example, the governance systems would be organizations that manage fishers, the users would be the fishermen, and the units would be the number of lobsters caught. All aspects of this social-ecological system example can act independently and have their own role to play, but then come together to produce a complex SES of fisheries. This example also illustrates the varying scale of SESs, as individually fishers and lobsters are small, but together form a large-scale system of fisheries. Therefore, all subsystems must collaborate and adapt to one another to effectively produce a sustainable SES. Understanding the complex nature of ESS can lead to ensuring their long-term resilience. Unlike traditional views that separate human society from nature, the SES framework posits that humans are an integral part of nature, shaping and being shaped by ecological processes (Hendry et al., 2017).

According to a study, the SES framework moves beyond simple cause-and-effect relationships to embrace complexity, feedback loops, non-linearity, and multi-scale dynamics (Ostrom, 2009). The following key characteristics and components of an SES typically include:

Interdependence: Human actions have direct and indirect impacts on the ecosystem, and conversely, changes in the ecosystem directly affect human well-being and social structures. For instance, deforestation by community members may impacts river quality, which then affects their fishing livelihoods (Hendry et al., 2017).

Complex Adaptive Systems: SESs are not static but are constantly evolving, adapting, and responding to internal and external disturbances. They possess emergent properties that cannot be predicted by analyzing individual components alone (Herrero-Jáuregui et al., 2018; Leslie et al., 2014).

Feedback Loops: These are crucial to SES dynamics. Positive feedback loops can accelerate degradation (e.g., deforestation leading to soil erosion, further limiting forest regrowth), while negative feedback loops can promote stability or resilience (e.g., community conservation efforts leading to resource recovery) (Lee, 2025).

Thresholds and Tipping Points: SESs can absorb a certain level of disturbance, but beyond a critical threshold, they may shift abruptly and irreversibly into a different state (e.g., a productive fishing ground becoming a polluted dead zone).

Resilience: The capacity of an SES to absorb disturbance and reorganize while undergoing change so as to retain essentially the same function, structure, identity, and feedback loops. It's about persistence and adaptability in the face of change.

Multi-scale Dynamics: SESs operate across multiple spatial (local to global) and temporal (short-term to long-term) scales. Actions at one scale can have profound impacts at others, necessitating multi-level governance.

Other authors have described SES as a system that connects two subsystems of social (human) and ecological (biophysical). These two subsystems are inherently interdependent. A more complex definition of SES is an "Integrated system in which human society and its multiple cultural, political, social, economic, institutional, and technological expressions interact with ecosystems (p.1) tends to identify a close relationship between two systems: the social and the ecological. The social component of SES typically deals with politics, history, economics, and ethics, among other institutions. The ecological component of SES deals with the natural habitats, animals, aquatic health, and changes in climate.

A social-ecological systems perspective provides a framework for understanding the complex dynamics occurring between environmental and societal changes. It highlights the intense dependency that society has on the natural environment. From a social-ecological systems perspective, uncertainty is an inherent part of all systems. A systems' adaptive capacity describes its ability to respond to potential damage, take advantage of opportunities, or respond to consequences. The adaptive dynamics of SES allow for the creation and success of governance systems. The marking of a sustainable and long-term SES is the ability to adapt to many variables that arise over periods of time.

According to a study framework for analyzing SESs often disaggregates them into core subsystems and associated attributes, including (Petrosillo, 2015; Ostrom's, 2009):

Resource Units (RU): The products or benefits derived from the resource system (e.g., fish, water, timber, non-timber forest products).

Users (U): The individuals or groups who utilize the resource units.

Governance Systems (GS): The rules, norms, and organizations that regulate resource use.

Interactions (I): The reciprocal actions between components (Lee, 2025).

Social, Economic, and Political Settings (S): The broader context influencing the SES.

Related Ecosystems (ECO): Other ecological systems connected to the focal SES.

The Dibombe River study directly embodies the principles of an SES, providing a robust conceptual lens through which to analyze the intricate relationships between the communities and their riverine environment. The study identifies the Dibombe River itself as the central resource system (RS) and its provisioning ecosystem services as Resource Unites (RU). Hence, the "patterns and use/benefits of ecosystem services" directly correspond to understanding the resource units (e.g., fresh water for drinking/domestic use, fish, agricultural land, timber, non-timber forest products) that communities extract and depend upon. The research acknowledges these as "essential provisioning services" for "human survival and wellbeing." The "communities along the Dibombe River" are the primary users whose "heavy reliance on the river for livelihoods". This helps to positions them as central actors within this SES. The study assesses their perspectives, practices, and vulnerabilities directly. The study explicitly addresses "numerous environmental challenges" such as "rapid degradation, deforestation, poor waste management," and "increase pollution." These are negative human-induced interactions that generate detrimental feedback loops within the SES (e.g., deforestation leads to soil erosion and river sedimentation, which impacts fish populations, subsequently reducing "income, food insecurity, and health risks" for the users).

The socio-economic implications of this framework highlighted the direct impact of ecological degradation on human well-being, underscoring the socio aspect of the SES and with these challenges come stakeholders' efforts and policy implementation which constitute the governance system (GS). These provide the framework for assessing stakeholders' efforts in addressing these challenges within the Dibombe River SES. This includes formal policies (lack of policy implementations) and informal conservation initiatives and sustainable practices by various actors. The identified limited awareness and finance are critical challenges to effective governance within this SES. Also, the aspect of land use changes within the study area indicates the dynamic nature of the Dibombe River SES, thus highlighting how human activities are constantly altering the system. There is therefore the need for collaborative management approaches that balance human well-being with ecosystem conservation" (as a key recommendation) directly speaks to the necessity of fostering resilience and adaptive governance within the SES to ensure long-term sustainability. By applying the SES framework, this study moves beyond a simple enumeration of problems to understand the underlying causes and consequences of environmental degradation in an integrated manner. It provides a structured approach to analyze the drivers of change, the responses of human actors, and the resulting impacts on both ecological health and human well-being, thus informing more effective, holistic, and sustainable management interventions for provisioning ecosystem services along the Dibombe River.

3. Study Area And Methods

3.1 Study Area

This study focuses on selected communities situated along the banks of the Dibombe River within the Littoral Region of Cameroon. The Dibombe River Basin, particularly its lower and middle stretches, represents a critical ecological zone that provides diverse provisioning ecosystem

services crucial for the livelihoods and well-being of the surrounding local populations. According to the population and housing census of Cameroon, in 2005, the population of the Littoral Region where the river is located is approximately 3,354,978 inhabitants and comprises four Divisions namely: Nkam, Moungo, Wouri and Sanaga Maritime. The study area is located between Latitude 4°00'N to 4°45'N of the Equator and Longitude 9°30'E to 10°00'E of Greenwich Meridian. This range encompasses various rural and semi-urban settlements directly adjacent to the river (Figure 1.). The key urban centers include; Douala (the economic capital) to the South West and Nkongsamba (a significant agricultural hub) to the north provide proximity influences market access for provisioning services, demographic pressures, and the potential for both economic development and environmental degradation.

The study area covers approximately 500-700 square kilometers along the specified river stretch based on the assumed linear extent and average width of community influence zones. Nkam Division one of the divisions under study covers a surface area of 6,291 km² and consisting of four Sub-Divisions which in 2001 had a total population 66,979 inhabitants (BUCREP, 2015). The population of Yabassi Sub-Division the head-quarter of Nkam is estimated at 14,685 inhabitants based on the Yabassi Health District estimation of 2011. The primary boundary is the Dibombe River itself, which acts as a central axis. The lateral boundaries are defined by a reasonable buffer zone extending from the riverbanks to encompass the most reliant communities and their immediate resource-use areas. Administratively, the study crosses 48 villages in Wouri, Moungo and Nkam Divisions respectively. The major ethnic groups that constitute this population are the Bassa, Bandem, Banya, Bonkeng, Bodiman and Ewodi.

Over time, the population has become increasingly cosmopolitan with people coming from other parts of the region and other parts of Cameroon (with the North-West and South-West Regions being predominant incomers due to socio-political conflicts in these two regions. The migrants are engaged mainly in agricultural activities due to the equatorial or tropical monsoon climate, characterized by high temperatures and high humidity throughout the year. There are generally two main seasons: a long-wet season (approximately March to November) with heavy rainfall, peaking around July-August, and a shorter, less intense dry season (approximately December to February). Annual rainfall typically ranges from 2,500 mm to 4,000 mm, with average temperatures hovering between 25°C and 28°C. Elevations are typically modest, ranging from sea level near the river's mouth to around 100-300 meters above sea level further inland. The river itself is characterized by a relatively gentle gradient, leading to meandering courses and the formation of extensive floodplains and marshy areas along its banks, particularly prone to seasonal inundation as it flows through coastal lowlands before emptying in to the Atlantic Ocean. The choice of this study area is predicated on its rich natural resource base, observable human-environment interactions related to ecosystem service utilization, and the increasing pressures on these resources.

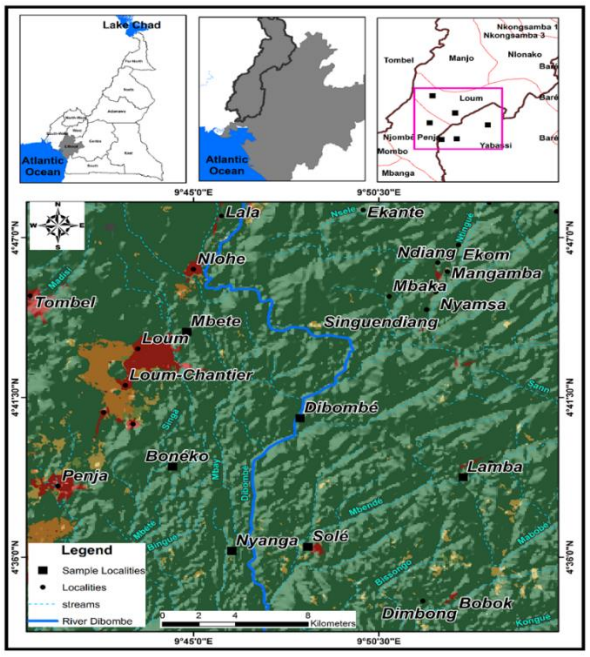

Figure 1: Sample Study Site along the Dibamba River within the Littoral Region, Cameroon (Source: Adapted from the Administrative Map of Cameroon (2016)

3.2 Sampling, Data Collection and Analysis

The study adopted a convergent parallel mixed-methods research design. Quantitative data (via surveys) provided statistical evidence on reliance patterns, prevalence of challenges, and socio-economic implications across a larger sample, while qualitative data (via interviews, focus group discussions, and field observations) offered rich, detailed narratives to explain the "why" and "how" behind these patterns, particularly concerning human-environment interactions, policy implementation gaps, and stakeholder dynamics. The findings from both data sets were then integrated during the interpretation phase to provide a holistic understanding of the complex socio-ecological system of the Dibombe River communities. For the administration of questionnaires, eight interviewers (six females and two males) were selected based on previous field experiences, aptitude, and knowledge of the study area. Under the lead of a principal socio-economist, they were recruited and trained during January 2021 in Yaoundé and deployed in the field from the 7 to 14 February 2021 in the Nkam, Moungo, Wouri and Sanaga Maritime Division. It is important to note that at the end of the training exercise, a pre-testing of the questionnaires was done with a sample of households on the outskirts of Yaoundé and appropriate modifications were made to the questionnaires.

A structured questionnaire was administered to 300 community members (aged 18 years and above) who were permanent residents within the selected communities along the Dibombe River and were willing to participate in the survey or Focus Group Discussions (FGD). A stratified random sampling method was employed to ensure representativeness across the diverse communities along the Dibombe River taking into consideration the size of the population of each community. The strata were defined by distinct communities or geographical segments along the river's course to capture potential variations in reliance patterns, resource availability, and exposure to challenges (e.g., proximity to industrial zones). Within each stratum, households or their representatives in the absence of the former was selected using a simple random sampling technique and one adult member from each selected household was invited to participate. This approach aimed to provide a broad and statistically representative overview of the communities' perspectives. Exceptions were made in situations where all the target key household respondents were unavailable. The selection of communities with which to work depended on proximity and accessibility to the river.

For instance, in the Yabassi Sub- Division, the following villages: Sole, Ndibong, Ntabako, Lamba (Ndogmenia, Ndogmaka and Ndognac) were sampled. According to Cochran's sample size formula developed in 1977 where no = t2 s2/d2 was used to calculate the number of questionnaires to be administered in each village (although slight modifications were made in the field) – Where (Barlett et al., 2001):

no is the required sampled size based on the statistic chosen for the value of t, s and d

t = value for selected alpha level of 0.10

s = estimate of standard deviation in the population of 1.65

d = acceptable margin of error for mean being estimated at 0.03

After the determination of no, the finite sample population size was calculated from the total population using the formulae below:

n= no/(1+(no/population))

This formula produces the following table when:

Population size scale sampled population size (n) at

t = 0.10; s = 1.65; d = 0.03

P □ [50- 100[30

P □ [100- 200[46

P □ [200- 300[59

P □ [300- 400[65

P □ [400- 700[72

P □ [700- 2000 [78

P > 2000[83

A total of 300 questionnaires were administered in the various communities likely area facing challenges of ecosystem services and degradation with population size influencing the number of questionnaires administered per community) (Table 1). Considering the communities, Sole has a population of 2,000 inhabitants and to this effect, 156 questionnaires were administered. Comparatively, in Ndibong with a population of 500, 45, Lamba with 600 inhabitants, 62 and Ntabako with 300 inhabitants, 37 questionnaires were administered.

Table 1: Sample Population and Questionnaire Administration to Inhabitants

Communities	Target Population	Sampled Households	Interviews
Ndibong	300	45	8
Ntabako	300	37	
Sole	2,000	156	
Lamba	600	62	
Total	3,200	**300**	**10**

Source: Extracted from Population Statistics (2015)

From these strata (Table 1), a total of 300 households were randomly selected for questionnaire administration and 8 interviews were done in a proportionate manner as the sampled population for the study, so as to avoid representation bias. Thus, a total of 300 respondents constituted this study gotten from the (Barlett et al., 2001).

Interviewers were paired in twos and the team moved as one entity in each community. A diverse range of stakeholders was targeted, including but not limited torepresentatives of technical or other services and structures, such as health, education, agriculture, trade, transport, fisheries, life stock as well as some elderly men and women who were able to elaborate the history and culture of communities in the study area, local chiefs, environmental agency representatives, agricultural extension workers, and local industry representatives as well as some elderly men and women who were able to elaborate the history and culture of communities in the study area for in depth interviews based on their direct involvement in environmental management, community development and resource governance.

Focused group discussions organized with different groups of people in the communities considering gender, profession/occupation and position in the community. The aim of this Focus Group Discussions was to complement information on knowledge, beliefs, attitudes, and perceptions of people which were unavailable, incomplete or imprecise as gathered using other techniques. It was also to compare and triangulate information from data obtained using other information gathering methods. In total, six FGDs were organised in the Yabassi Sub-Division. Specifically, three were organised respectively in Sole and Lamba. The FGD in Sole brought together participants from Ntabako, Ndibong, and Sole, while the one in Lamba brought together participants from the three villages of Lamba. The grouping of participants from the different villages took gender, age group and distance into consideration. Participants varied from six to 12 per FGD target. This was led by a facilitator who was assisted by a note taker and instrument manipulator who doubled as a non-verbal behavioural observer. The main tool used was the FGD questionnaire guide accompanied by a tape recorder to record the information from participants. Recordings were transcribed following the completion of field work.

Field observations were conducted to provide recorded visual evidence related to land use, signs of environmental degradation (e.g., eroded riverbanks, waste accumulation), resource extraction activities, and the general state of ecosystem health. GPS camera was used to obtained geographic data on the major points, culturally valued sites and major infrastructure within villages was collected. A comprehensive desktop review was conducted to gather existing information relevant to the study area and the research topic from peer-reviewed journal articles, government reports, NGO publications, national statistics, climate data, and satellite imagery from several sources such as the internet, private and public libraries. This data provided crucial context, baseline information, and validation for primary findings.

After having collected the data, both qualitative and quantitative data analysis methods were used. Quantitative data obtained from the questionnaires were coded and entered into Statistical Package for the Social Sciences (SPSS) software (Version 23.0). Descriptive statistics (frequencies, percentages, means, standard deviations) were generated using Microsoft Excel (Version 23.0) to describe the socio-economic and demographic profile of respondents, their reliance patterns on ecosystem services, and perceptions of environmental challenges while inferential statistics, such as Chi-square tests and Pearson correlation, were employed to examine relationships between variables (e.g., between reliance on specific services and exposure to particular challenges; or between land use changes and socio-economic implications) and to formally test the stated hypotheses of the study. Audio recordings from interviews and focus group discussions were transcribed verbatim. The qualitative data were then analyzed using thematic analysis. This involved an iterative process of familiarization with the data, initial coding, searching for themes, reviewing themes, defining and naming themes, and producing the report. This approach helped to identify recurring patterns, perceptions, challenges, opportunities, and the nuances of stakeholder efforts related to ecosystem service provisioning. Results were presented using a combination of tables, figures, maps and narrative descriptions, supported by direct quotes from interviews and FGDs to illustrate key themes. Prior to commencing data collection, ethical approval was obtained from university of Douala Review Board and Ethic Committee for Research. All participants were provided with comprehensive information about the study while ensuring informed consent was obtained verbally or in writing before any data collection began. Participants were assured of their voluntary participation and their right to withdraw from the study at any time without penalty. Anonymity and confidentiality of participants' identities and responses were strictly maintained throughout the study, particularly for sensitive information.

4. Results And Discussions

4.1 Patterns and Use/Benefits of Ecosystem Services

The Dibombe River, located in Cameroon's Littoral Region, is a vital freshwater system supporting diverse ecological functions and providing essential ecosystem services to surrounding communities. Its riparian forests, wetlands, and agricultural landscapes offer a range of provisioning, regulating, and cultural services that underpin local livelihoods and biodiversity. Recent studies in the Dibombe River catchment, particularly within the context of infrastructure development projects like the Dibombe Hydropower Project, have highlighted significant variations in plant diversity and carbon storage across different land use types. Understanding the spatial and temporal patterns of ecosystem service utilization along the Dibombe River is essential for informing sustainable management practices. This includes assessing how different land use practices impact the availability and quality of services such as water purification, soil fertility, and the provision of Non-Timber Forest Products (NTFPs). Furthermore, recognizing the benefits derived from these ecosystem services by local populations and the challenges therein can aid in developing strategies that balance ecological conservation with socio-economic development.

4.1.1 Agriculture Services

Much of rural Cameroon is characterized by agricultural (most subsistence but with some commercial) on which the population is dependent for their livelihoods. Approximately 77% of the adult respondents surveyed practice agriculture and so survive on the sale of produce from their farms, 11.3% are employed in the state and private sector with a fixed monthly salary, part of which is characterized by delays in payment of salaries as seen. Figure 2 present the diverse sources of livelihood in the study area. The balances of the respondents are self-employed, mostly running small businesses of variable nature including fishing, hunting, mechanic and tailoring.

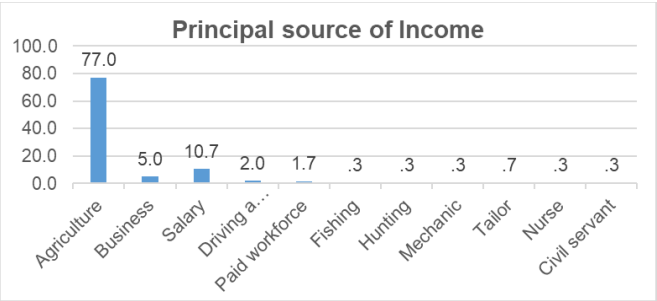

Figure 2: Principal source of household income (Source: Fieldwork, 2025)

As seen on Figure 2, agriculture is the main economic activity in the Nkam Division and most especially in the Yabassi Sub-Division and villages

within the Dibamba River area of influence. As mentioned above, about 77% of the surveyed population is engaged in agriculture as their main activity. This is subsistence agriculture, which uses mainly family labor. However, a few individuals recruit paid labour from the community members, usually when they are cultivating more than 1 ha. Some people farm as cooperatives and CIGs. In general, cassava, maize, plantain/banana, yams, coco yams and egussi are the most widespread type of food crops (95% of respondents). Dominant fruits include mangoes and oranges. Whilst cassava is the main crop is in all the divisions of the Littoral Region, bananas, egussi and yam are dominant in Nkam.

Although, the majority of farmers use rudimentary materials and cultivation techniques, they still obtain high yields due to the fertile soils and rainfall. Tools are mainly machetes, hoes and axes. Improved seeds and pesticides are rarely used by farmers, except famers who exploit large- and medium-sized farms. The mixed agro-pastoral farming system is widespread in the area and the agricultural sector is experiencing a boom as a result of the influx of internally displaced persons (IDPs) from other regions of Cameroon specifically from North West and South West Region. The price of agricultural produce varies seasonally and areas of production. Product prices are higher during the dry season because of improved accessibility and lower during the rainy season as a result of poor roads and inaccessibility.

Cash crops such as cocoa, oil palms and white pepper are also produced in the area. About 18% of respondents carry out animal breeding mostly for subsistence and partly for commercial purposes. The types of animals raised are chickens, pigs, ducks and goats (Plate 1). Concerning cash crops, it is important to note that 71% of respondents cultivate cocoa and oil palms while the balance cultivates crops such as white pepper.

Plate 1: Agricultural produce and animal breeding activities in the project area (Sole and Lamba) (Source: Fieldwork, 2025)

These activities generate huge sum of cash to the inhabitants of the study area. Hence, concerning the average household income in the communities surveyed, 41% of respondents indicated an average annual income of 350,000 FCFA, 28% from 350,000-1,500,000, 8% earn above 1,500,000 FCFA a year, 20.3% could not estimate and the balance (2.7%) said they do not sell anything and, therefore, do not earn anything. Typically, it is difficult to obtain these kinds of data, especially from rural populations whose income is not cash-based but rather relying on subsistence agriculture for livelihood survival. Hence, these income levels must be treated as estimates and with caution.

Furthermore, field assessment on the agroforests and cropland in the study area revealed that besides the thin riparian strips of native vegetation and relics of small forest, the remaining habitat is largely deforested and comprises a mosaic of country side habitats with farm huts, plantation plots and mixed agricultural plots. Extensive crop fields including fallows and plantations make up a vast majority of project's area of influence. Vast extends of monoculture plantations of oil palm are a common feature (plate 2). Farms are cultivated annually for other crops such as maize, yam and manioc and sometimes left for several years without cultivation for it to fallow.

Plate 2: Evidence of Cash Crop Farming in the Ndibong Study Area: Palm close to intake point a cropland / mix plantation extending to the immediate banks of the Dibombe River within the impoundment area of the weir (Source: Fieldwork, 2025)

The general view of the land use in this area shows advance degradation of the forest and its continuous transformation from forest land to open cropland and mixed shade plantations indicated on Plate 2. The pressure on the land use is seen in the recent cleared segments of the forest along the river observed during the surveys and the changes identified from one year to the other in the last two years that the ESIA surveys have been undertaken.

4.1.2 Water Supply

Water supply is a concern in most communities, with some communities receiving running water for a few hours a day, or no piped water at all. The majority of the population lacks access to safe drinking water. While there is water supply infrastructure in Nkam divisions, pipe-borne water is available primarily in the major centers, with most people in the rural communities using raw water from drilled wells or boreholes (provided by the government and donor organizations but on which local communities do not rely because, as an example, the single borehole in Sole is often crowded). In some communities, water is sourced from hand dug traditional wells (plate 3), streams, rivers, and channeled springs and rainwater during the rainy seasons. Water is meant for, laundry, drinking and bathing. Given the paucity of water infrastructure and the lack of treated water that is safe to drink and with which to cook, i.e. potable water, access to safe water is a developmental priority of households/ communities in the project area.

Plate 3: Part of population collecting water from the single borehole in Sole (Source: Fieldwork, 2025)

4.1.3 Harvest of Non-Timber Forest Products (NTFPs)

The forests in the study area are used for diverse purposes such as the collection of NTFPs, hunting and wood cutting. Several people are involved with NTFPs, comprising men, women and children. 47% of households interviewed reported collecting plants in the forests, including berries bitter cola, also call "nyeki", eru, bush mango; spices such as "Njansa", white pepper, black pepper, four Conner (cercer), "Dibeduko" "homi", "Mandodo" spice, "madongdong", "four Conner", "mbongo", "mbola", cashewnuts, "alagata" pepper, "country onion" and "pebe". It was revealed that eru is mostly harvested by Bamenda people, particularly from the Essimbi tribe, who operate as family businesses involving all members of the family. They are English-speaking and mostly IDPs. Eru is abundantly harvested in the dry seasons compared to the rainy seasons. Bush mango and noisette which is eaten as groundnuts or used to cook kokias as well as cashu-nuts are harvested by picking.

This is done by virtually anyone who goes into the forests. Bitter cola is both cultivated and picked in the forest. The collection of spices like black pepper used in cooking bongo-chobi, is also harvested by everyone, as is "four corners". Infact, everyone harvests NTFPs. Njansan is collected on farms but people may not harvest on another person's farm. Most of the NTFPs are consumed at home or sold to retailers (byam-sellam). Some NTFPs are dried because there are seasons of scarcity. Apart from eru, most of the NTFPs are abundant during the rainy season and precisely in the month of August/September. Some NTFPs are used for medications like the bark of trees known as ''ecorse jaune" (yellow bark), "colilanga" used to treat babies from diverse types of diseases, and "ekouk" used to treat yellow fever in children. The proportion of respondents involved in the harvest of NTFPs per village as obtained from the questionnaire survey are presented in Table 2.

Table 2: Percentage of respondents involved in the harvest of NTFPs per surveyed village

Community	Djansan (%)	Black pepper (%)	Eru (%)	Bush mango (%)	Four conners (%)	Bark of Enantia (%)	Bitter colar(%)	Bark of Ekouke (%)	Bark of Bubinga (%)	Cola nuts (%)
Sole	22	13	5	29	3	5	2	2	1	13
Ndibong	14	9	2	10						4
Ntabako	10	9	3	11		4	1		1	8
Lamba	21	12	10	11	4	7	2	4	4	5

Source: Fieldwork, 2025

4.1.4 Hunting

Hunting is a common activity in the project area but very few people are involved. Only 3% of respondents are involved in hunting. Of those who do hunt, men are assisted by their wives. For example, in Lamba, respondents reported that hunting is mostly done by Internally Displaced Persons from the North West and South West Regions. The game comprises small mammals (Gambian Rat, Tricuspid Scaled, porcupine, monkey, squirrels, civet cat, and common aulacode or cane rat), birds (hornbill, green parrot and red parrot) and reptiles. Much of the hunting is for subsistence. Children are mostly involved in the hunting of Gambian rats. Hunting is done in the forests using dogs, guns, knives, cutlasses, traps and spears. The products obtained from hunting are partly consumed with the rest sold. There are no major hunting restrictions - anyone is free to hunt, but it is forbidden to hunt animals classified as Class A, such as buffalo and chimpanzee. Also, hunting is forbidden in forest reserves although this is ignored by some locals. The peak hunting season is June to August and hunters can make between 25,000 fcfa to 50,000 fcfa per month. Most of the people who practice hunting do it as a secondary activity. Women do not hunt but they do accompany their husbands when they hunt.

4.1.5 Fishing Activities

Fishing is also a common economic activity in the project area but practiced by very few people. Only 2.7% of respondents reported to be involved in fishing. The fishermen are categorized into farmer-fishermen and professional-fishermen. Farmer-fishermen are the men and women who do fishing once in a while from nearby streams for home consumption. Professional-fishermen are those who see fishing as their profession and who sell their catch as a means of sustaining livelihoods. For example, in Sole, there is one known professional-fisherman who goes further afield to fish in rivers like the Dibombé and Njanga, usually using a canoe and nets. Farmer-fishermen do foot fishing using basins, nets and traps. Fish are sold fresh or smoked and some are consumed at home. Monthly sales for a professional fisherman are 100,000 FCFA and yearly sales are 1,000,000 FCFA excluding transport. In the rainy season, which is the peak fishing season, monthly sales can double to 200,000. Most of the fishermen are Cameroonians; therefore, there are no restrictions on fishing. However, restrictions are imposed when foreigners attempt to fish without paying for their right to use a stretch of river for fishing. The types of fish in the project area are stock fish, Viper fish, sole, and Carpe, makeroe and red feather (plate 4).

Plate 4: General view of the riparian forest along the banks of the Dibombe river also where the fish on sale in Sole are displaced came from (Source: Fieldwork, 2025)

Some indigenous Bassa people fish part time using canoes, nets and traps, fishermen from Bertoua or Eastern Region of the country do fish here in swamps while locals fishermen do it around the Mbende River which is within walking distance of the Dibombé River. Fish is usually sold in heaps and from 500, 1000 and 2000 FCFA depending on the quantity. The quantity presented on Plate 10 is sold at1000 FCFA each

4.1.6 Wood harvesting

None of the 300 respondents to the questionnaire survey reported selling wood commercially (this is despite the abundance of forested areas in the project area). This suggests that wood cut is for personal use as firewood and for house construction as presented on Plate 5. Officially, people have to pay for logging permits, which allows them to harvest agreed amounts from specific areas. In this context, the actual number of people engaged in wood cutting, especially engaged in the selling wood commercially, may be higher than reported as some of these activities are clearly being undertaken illegally and, therefore, people do not want to admit to being engaged in illegal woodcutting and selling.

Plate 5: Evidence of Pterocarpus soyauxii illicitly logged a landscape showing approximately 1ha of riparian forest cleared for agricultural expansion (Source: Fieldwork, 2025)

4.2 Environmental challenges faced by communities and its socio-economic implications

The Dibamba River is a vital ecosystem for communities living along it banks providing natural resources for thousand inhabitants. However, the river is facing multiple threats including urban development, pollution, climate change, sand mining among others. Human activities have an influence on ecosystems services either directly or indirectly causing degradation of ecosystem services. Some of the indirect causes include rapid urbanization which has resulted into pollution, habitat destruction and inadequate infrastructural management. The rapid population growth of coastal areas does not tend to produce many socioeconomic benefits, but will exert more pressure on the environment and ecosystem services.

Conflicts that always result in displacement and unemployment of youths often result in them settling in urban areas which are perceived as sites for employment. This mass movement and unemployment often leads to an overexploitation of resources for livelihood (anthropogenic pressure) through activities such as poaching, over fishing, bush fires causing direct causes: climate change, pollution (air, soil, water), overexploitation of

species, destruction of species' habitat and the eutrophication. These direct causes lead to ecosystem degradation, loss of value, erosion of genetic diversity and extinction of species. The degradation of ecosystem services is hurting most vulnerable people, and is sometimes the biggest cause of poverty.

Again, huge statistical changes in urban population growth coupled with their subsequent socioeconomic impacts upon education, health, transportation, sanitation, and physical security. Urban areas located in flood prone areas are at increased risk of floods, as well as inundation and erosion (Douglas et al., 2008). More and more concerns are raised with flooding disasters and increased damages caused by flood (Jonkman et al., 2008). Extra water during heavy rain can dramatically increase the rate of flow through wetlands and rivers, stripping vegetation and destroying habitats along river banks. It can also cause damaging floods downstream and lead to an increase in water pollution. Such flooding will result in water quality degradation which are often associated with health problems because of the presence of microorganisms. Data from the field stipulated that malaria is the primary cause of mortality and morbidity with a prevalence rate of 92%% and water borne related diseases like diarrhoea are very visible in the area. Prevalent diseases in the project area are widespread malaria (39.2%), typhoid (32.1%) and the common cold (20.7%). Other health problems in the project area include diarrhoea, filarial, yellow fever, rashes, intestinal worms, skin-rachis and cardiovascular diseases (figure 3) The most vulnerable groups for malaria are children and pregnant women.

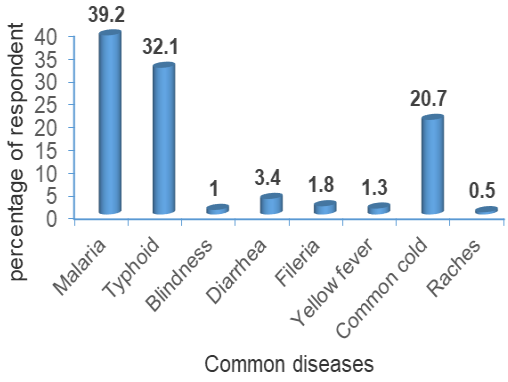

Figure 3: Common Diseases in the project area (Source: Fieldwork, 2025)

Discussions with interviewees as well as health-care personnel at the Sole Health Post revealed that the major causes of the above health problems are the absence or lack of potable water, poor hygiene practices by some members of the population (e.g. wells dug next to toilets), and poor drainage systems resulting in stagnant water favouring the breeding of mosquitoes. By way of example, in Sole, there is a single functional borehole for the entire community which provides raw (i.e. untreated water) (there are three dysfunctional boreholes, which have been dysfunctional for several years). In other communities visited during field work, no evidence of piped water or boreholes. Of the 300 questionnaires administered, 41.3% of respondents said they obtain drinking water from boreholes; however, it is untreated, raw water as confirmed by respondents and the general population. The balance of respondents (58.7%) obtain drinking water from streams, springs, traditional wells (shallow and unprotected wells}, rivers and rainwater during the rainy season. An example of poor attention to hygiene is people bathing in the same spot or streams as from where they draw water for domestic purposes. While some people see this as a major problem to their health, others are of the opinion that it is not a problem because their ancestors drank from the same sources without ill-effects. The rate of household access to potable water and to water toilets in the study area is low. Majority of population get their drinking water from traditional wells, standing water, streams and bole holes (drilled wells). When respondents were asked how they feel about drinking from a river, some said “It is natural and we grew in it. So, we drink it and do other things there”.

Concerning sanitation and hygiene, there is no cleaning, waste collection and treatment services or suitable drainage systems in the different communities visited during field work. As a consequence, domestic and commercial waste is either burned or dumped in the open as indicated on the figure below. (e.g. Farmlands, running rivers, public and private burning.). It is important to know that what the respondents referred to as public trash can is simply a spot where waste is deposited and is later burned in the open. These create health hazards and provide fertile breeding grounds for mosquitoes (which are particularly problematic given the already high incidence of malaria (Figure 4).

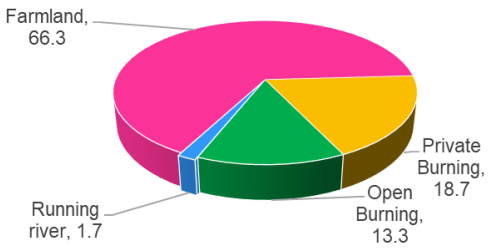

Figure 4: Percentage representation of waste management (Source: Fieldwork, 2025)

It was noted that the utilization of health facilities in the project area is low. This is due to the practice of alternative treatment, the remoteness of health facilities and the absence of community pharmacies and very few unequipped clinics. The only health center that caters to all the communities surveyed in the Yabassi Sub-Division as relevant to the proposed HPP is the Sole Health Centre. A significant proportion of populations live far from this health Centre. This is due to the far-off nature of some villages from Sole (Figure 5). According to ARCADIS (2025), Douala rapid growth since the 1950s has led to the destruction of natural systems such as mangrove forests that one’s surrounded the banks of the Dimbama River. This development along with poor waste management in informal neighbourhood and industries has increased pollutions levels in the river. To address the challenges faced by communities UN Habitat has recognised the importance of the river and has enlisted the Arcadis Shelter Program to help develop a strategic resource management plan to protect the river from further environmental degradation and damage and also ensure it sustainable management.

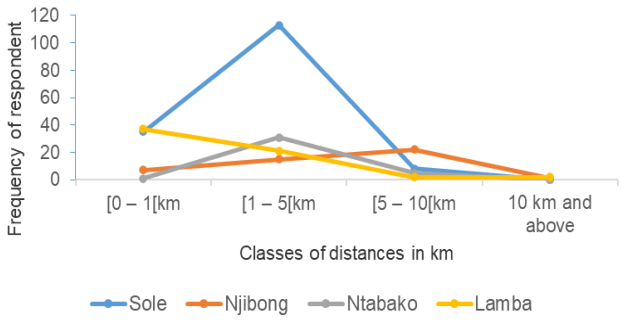

Figure 5: Distance from the house to the nearest healthcare centre per community surveyed (Source: Fieldwork 2025)

Arcadis further noted that despite the challenges of exploiting provisioning ecosystem services in the river, the river continue to remains an essential ecosystem that provide water, food, access to the sea and relief for storm water and waste water (Arcadis, 2025). It also holds cultural significance for the local community and is the main source of drinking water for the population in the three divisions. Hence, maintaining the balance between different socioeconomic economic, cultural and ecological values is critical for long term health of the river. Hence, local and government stakeholders including NGOs are making strives to protect the river and ensure that it continues to provide economic, public health and cultural benefits to the community

5. Conclusion And Policy Recommendations

This study, conducted along the rapidly developing industrial zones of the Littoral region of Cameroon, aimed to comprehensively understand the dynamics of provisioning ecosystem services within local communities along the Dibombe River. The findings affirm the indispensable role rivers play in human survival and well-being, providing essential services such as water, food, and livelihoods. Specifically, an overwhelming majority of respondents, over 78%, indicated a heavy reliance on the Dibombe River for their livelihoods, underscoring its critical importance to the local socio-economic fabric. Despite this profound dependence, the study conclusively reveals that the Dibombe River and its adjacent communities face severe environmental challenges. These include pervasive pollution, extensive deforestation, and the overarching impacts of climate change, exacerbated by poor waste management, unsustainable development priorities, and

over-harvesting. These environmental pressures translate into significant socio-economic implications for the local population, manifested as reduced income, heightened food insecurity, and increased health risks. These adverse outcomes are directly linked to unsustainable land-use changes and critical gaps in policy implementation and environmental awareness. While various stakeholders have initiated commendable efforts to address these multifaceted challenges through conservation initiatives and the promotion of sustainable practices, their effectiveness is consistently hampered by limited public awareness and insufficient financial resources.

Therefore, the study concludes that the current trajectory of resource utilization along the Dibombe River is largely unsustainable, threatening both human well-being and the long-term ecological integrity of this vital socio-ecological system. Sustainable management necessitates a fundamental shift towards collaborative approaches that meticulously balance human development needs with ecosystem conservation imperatives. There is the need for stakeholder to develop a strategic river resource management plan to protect the river including it corridors, regulate and monitor waste disposal in the river, while improving the development planning. There is also the need to create a permitting system for river resources and promote cultural ties to the river. To ensure long term viability of this initiative, there is the need for an adaptive management structure to evaluate the success and challenges of the plan. Local and regional development plans must formally integrate the value of provisioning ecosystem services, ensuring that industrial and urban expansion projects undergo thorough environmental impact assessments that prioritize the health and sustainability of the Dibombe River.

The government and relevant regulatory bodies should urgently develop and rigorously enforce comprehensive environmental policies tailored to industrial zones, specifically addressing river pollution, waste management, and riparian deforestation. This includes implementing stricter penalties for non-compliance and ensuring transparent monitoring mechanisms. The municipal authorities and government agencies should also streamline processes for obtaining permits related to land use, waste disposal, and resource extraction, while simultaneously increasing public awareness about these regulations and their importance. Also they can ensure sustainable Resource Management through investment in accessible, and affordable waste collection and treatment systems for both industrial and domestic waste along the Dibombe River while promoting recycling and responsible waste disposal practices within communities and industries.

NGOs should **e**ncourage and support the adoption of sustainable agricultural practices, responsible fishing methods, and alternative livelihoods that reduce pressure on the river's resources. This could include training in eco-tourism or sustainable aquaculture. Also, they can launch targeted reforestation programs along the Dibombe River's banks using native species to prevent soil erosion, improve water quality, and restore natural habitats. Establish and protect riparian buffer zones from encroachment. They should also empower local communities to actively participate in the management and monitoring of the Dibombe River's resources. Establish and support community-led committees responsible for conservation initiatives, conflict resolution over resource use, and maintenance of shared facilities. Also, municipal authorities should develop and implement targeted public awareness campaigns using local languages and culturally appropriate methods to educate communities about the importance of the Dibombe River's ecosystem services, the impacts of pollution and deforestation, and sustainable practices. This should highlight the direct link between river health and their well-being. NGOs can also provide communities with knowledge, tools, and resources to adapt to climate change impacts affecting river services, such as developing drought-resistant farming techniques, establishing water harvesting and storage solutions, and implementing early warning systems for floods or extreme weather events. They should be initiatives develop to explore and secure diversified funding sources, including government allocations, international grants, private sector contributions (e.g., through corporate social responsibility), and potentially innovative mechanisms like payments for ecosystem services schemes, to ensure the long-term financial sustainability of conservation and management efforts. Lastly, encouraging and facilitating stronger collaboration among local communities, government agencies, industrial actors, NGOs, and research institutions. Establishing platforms for regular dialogue and joint action will be crucial for developing integrated solutions that address complex environmental and socio-economic challenges along the Dibombe River.

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