World Sustainability Series

Walter Leal Filho
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Sustainable Policies and Practices in Energy, Environment and Health Research

Addressing Cross-cutting Issues

Springer

World Sustainability Series

Series Editor

Walter Leal Filho, European School of Sustainability Science and Research, Research and Transfer Centre "Sustainable Development and Climate Change Management", Hamburg University of Applied Sciences, Hamburg, Germany

Due to its scope and nature, sustainable development is a matter which is very interdisciplinary, and draws from knowledge and inputs from the social sciences and environmental sciences on the one hand, but also from physical sciences and arts on the other. As such, there is a perceived need to foster integrative approaches, whereby the combination of inputs from various fields may contribute to a better understanding of what sustainability is, and means to people. But despite the need for and the relevance of integrative approaches towards sustainable development, there is a paucity of literature which address matters related to sustainability in an integrated way.

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Preface

This book aims to provide a contribution to a more comprehensive and interdisciplinary understanding of the cross-cutting issues on energy, environment and health research topics. These subjects are closely connected, and although interdisciplinarity implies a commitment between all fields of science, working together to provide knowledge that could result in the promotion of quality of life, this is not always implemented in practice.

The relationships between sustainable policies and practices on the one hand, and energy, environment and health research on the other, are scarcely exploited in an integrated way. Yet, a broad understanding of all interconnected issues helps towards their integration and this is a positive trend in the sense that it provides outcomes for existing similarities. Such associations also contribute to highlight a cross-cutting problem of contemporary governance and it is up to science to discuss it, aiming to achieve more informed and integrated policies.

A further element which is in favour of integrated approaches is that they may allow different stakeholders to work together. This includes universities, companies, governmental and non-governmental organisations and civil society, which, combined, may articulate together to not only discuss common problems, but also to reach possible solutions.

This book, produced by the European School of Sustainability Science and Research (ESSSR) and the Inter-University Sustainable Development Research Programme (IUSDRP), gives a special emphasis to state-of-the-art descriptions of approaches, methods, initiatives and projects from universities, stakeholders, organizations and civil society across the world, concerning cross-cutting issues in energy, environment and health research.

The book is structured in 3 parts:

Part One—Sustainable Concerns, Beliefs and Values
Part Two—Interdisciplinary Approaches and Methodologies
Part Three—Sustainable Practices and Solutions

These, in turn, address the following aspects:

- Discussions on practical experiences from different stakeholder groups towards sustainable development and cross-cutting issues in energy, environment and health
- Descriptions on the implementation of sustainable development initiatives to solve cross-cutting issues involving energy, environment and health
- Examples of partnerships and networks on sustainable development persuing energy, environment and health cross-cutting issues
- Perspectives of policy and governance towards sustainable development
- Successful experiences involving various sectors of society
- The interconnection between social inequalities and cross-cutting issues in energy, environment and health topics
- Agenda 2030 related issues

A special feature of this book, is that it not only presents a wide range of perspectives, approaches, methods and analyses about sustainability policies and how they relate to energy, environment and health research, but also documents and disseminates specific case studies, which show how this integration may be accomplished in practice.

We would like to thank all authors and reviewers for making available their experience in their chapters, and the willingness to share their ideas. By providing their inputs, the authors have made a positive contribution towards a debate which needs to be continued, and reach a depth far beyond what conferences, workshops or seminars may be able to offer.

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Sustainable Concerns, Beliefs and Values

Sustainability Perception of Lotic and Lentic Ecosystems in the Amazon Basin Through the Lens of a Local Community

Ana Sibelonia Saldanha Veras, Diogo Guedes Vidal, Nelson Azevedo Barros, and Maria Alzira Pimenta Dinis

1 Introduction

In the context of hydric resources distribution, Brazil holds the highest hydric availability on the planet, being responsible for almost all the total average change of water bed stream in South America. Brazil has an unequal distribution of its resources, specifically considering the Amazon basin, located in a region with low population density. Therefore, to study the lotic ecosystem is relevant, particularly in the Amazon region, to provide knowledge on lakes comprehension, i.e., naturally formed depression that stores freshwater, and hydrological conditions that play a key role in interactions with terrestrial processes, essential to sustain life through the quality of water in many *igarapés* (streams), i.e., small rivers. This ecosystem is part of the Earth's bloodstream, vital to individuals survival, as well as for nature balance, food and raw material provision, playing a crucial role in remote communities, namely those located in the Amazon Basin.

Water is the second most important component of the Earth, in addition to air, used as irrigation for crops, cooling equipment, industrial chemical processes, city growth, hygiene, as geopolitical divider and means of connectivity, navigation, leisure and recreation (Sabo et al. 2010; Falkenmark 2016; Herrera et al. 2019; Bogardi et al. 2020; Güntzel et al. 2020; Wetser et al. 2020; Plummer and Baird 2021). Individuals cannot survive without water. Accordingly, freshwater man-

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agement has resulted in several concerns and discussions in world forums (e.g., Brundtland Report—Our Common Future), a historical milestone in which sustainable development concept was defined as "… meeting the needs of the present without compromising the survival of future generations". This concept was widely shared in the (United Nations 2000). Thus, the Conference on the Environment—Rio 92, which allowed advances and the adoption of the 21 Agenda, presenting the need to understand the social, cultural, territorial, economic, political (national and international), and environmental dimensions, on the effects of the rapid climate changes and, consequently, on the Earth limits and resilience to support it. Alongside, sustainable tourism practices (i.e., leisure, sport and geotourism) must be committed to a sustainable development vision, depending on proper environmental management, to ensure long-term sustainability (Hummels and Argyrou 2021; Managi et al. 2021; Mihalic et al. 2021).

Considering the background, this work aims to identify the perceptions and attitudes of a local community in the Amazon Basin on lotic and lentic ecosystems in the context of Geotourism activity and its implementation to achieve the Sustainable Development Goals (SDGs). The main sustainability challenges of SDGs 6, 10, 14 and 15 are presented as well as the existing infrastructure to support Geotourism activity.

1.1 Overview of Ecosystem Services of Rivers and Lakes

Ecosystems are open systems comprising environments, both abiotic and biotic, that interact in processes contributing to human well-being, either directly or indirectly. They provide scientific evidence for stakeholders, i.e., public managers and natural water managers, as well as policymakers, to visualise environmental scenarios for future decision-making. In this regard, it is worth noting that these services have been a subject of concern, and their genesis was defined by Walter Westman (1977 *apud* Costanza et al. 2017) in his work "How much are nature's services worth?". This was followed by the development of the concept of "ecosystem services", advocating benefits for human well-being with a focus on the economic and ecological bias (Ehrlich and Ehrlich 1981; MEA 2005; Costanza et al. 2017; Butorac and Buzjak 2020; Aziz 2020; Tengberg et al. 2021). In this complex interaction, there is a heterogeneity of aquatic habitats, including rivers, streams, swamps, and lakes, which points to an enormous potential for research in various areas of the sciences due to its clear, transparent water ecosystems, related to the origins of the Amazon region (Morato 2018; Silva et al. 2020). Although lakes are a small component of the biosphere, they are valuable and necessary, as they cover five million square of the Earth's surface, according to satellite imaging studies (Verpoorter et al. 2014). The Brazilian Amazon, specifically the Northern region of Brazil, is comprised of the Amazon River basin, the most extensive basin on the planet, formed by 25,000 km of navigable rivers in about 6,900,000 km^2, of which approximately 3,800,000 km^2 are in Brazil. The Legal Amazon, as stated in

art. 2 of Law 5.173, of October 1966, includes the states of Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia, Roraima, Tocantins and part of Maranhão, and their ecosystems (Brazil 1966; IBGE 2010).

Lotic, e.g., rivers, and lentic, e.g., lakes, ecosystem consist of water bodies that are mostly found in depressed terrain and have no connection with the sea. The fluctuation of a lake's water occurs as a result of the water balance, which emerges from the interaction with the atmosphere, involving precipitation and evaporation, and groundwater, including hydrothermal water (Riccomini et al. 2015, p. 194). Therefore, freshwater ecosystem contributes to climate regulation, assisting nutrient cycling for vegetation, where ecological and biogeographic processes predominate. They are essential and indispensable to individuals living in remote areas, transporting water and materials, maintaining water quality and enabling human development, as these communities not only interact with the place but are also inhabitants of the biosphere and therefore beneficiaries of freshwater services over time (Folke et al. 2016; Janssen et al. 2021; Filocamo et al. 2020; Salinas-Rodríguez et al. 2021).

Amazon, a region with low population density, is a natural environment of floodplain areas, being considered one of the least known environments in the world and one of those that provide more ecosystem services, ensuring the maintenance of life and standing out as an essential ecosystem at a global level (Castello and Macedo 2015; Latrubesse et al. 2020). Despite the worldwide acknowledgement of Amazon contribution to global ecosystem balance, several studies pointed out the dramatic deterioration of these terrestrial and marine freshwater bodies, which implies global vulnerability, originated by overexploitation and with dramatic consequences to biodiversity, livelihoods, and human health (IBGE 2010; Bogardi et al. 2020).

1.1.1 Lotic and Lentic Resources: Rivers and Lakes and Human Use

Lotic and lentic resources in the Amazonian plain are the result of sediment deposition, flooding of floodplains or meander cutoffs. As part of global environmental change, geochemical cycles have received considerable attention from governments since the 1980s. Many lakes had their morphology changed in recent decades as they are affected by climate change and human activity, i.e., the human-induced changes. These lakes may be formed along large rivers when sediments from the main channel are deposited as dykes at the mouth of tributaries, forming a lateral lake, and are permanent in the landscape. Changes are reflected by lake water levels and by the provision of significant habitat for a diverse group of organisms (Hirata 2015; Tan Chao and Kuang 2017; Bucak et al. 2018; Tortajada 2020; Abbasi et al. 2020).

The hydrology of the Amazon basin is significant because it is configured as a enormous complex of rivers, streams, canals, creeks, and lakes with about 20% of all freshwater on Earth. Hydrochemical characteristics are influenced by the Andean mountains, where mineral-rich sediments originate, creating not only the typically

muddy colouration of waters but also originating turbulent waters, as well as watercourses from the Guiana Shield and Central Brazil (De Souza Paes and da Silva 2021).

Of all the regions on the planet, South America is one of the most vulnerable to climate change caused by natural factors, such as the temperature oscillation of the Atlantic and Pacific oceans, a phenomenon which is known as *El Niño*, and anthropic factors originated from the burning of fossil fuel, industrialization and wildfires, leading this region to being severely affected by climate change (Marengo et al. 2011; Lawrence and Vandecar 2015; Andrade et al. 2018; Juelsgaard 2020).

1.2 Sustainable Development Goals (SDGs) 6, 10, 14 and 15

According to the tourism strategy, there are 17 global goals to achieve a true and fair sustainable environment for all within the SDGs, part of the construction of economic, social and environmental indicators necessary for different regions of the planet, along with the 21 Agenda important global commitment. These goals unfold into 169 targets for the period from 2015 to 2030, established by the Assembly of the United Nations Organization-UN, ratified by 193 countries, these being the current sustainability challenges that aim to provide incentives for future generations, leadership, and institutions that carry out the management of environmental dimensions (Lópes-Alcarria et al. 2021).

As a component of the SDGs, geotourism is an activity that correlates geological heritage to tourism in rural areas that emerges in the 1990s. Its benefits are far from being fully known, but current evidence states that this activity can help to reduce rural exodus from remote areas once its development provides new job prospects by using the interpretation of aesthetic resources to address diverse audiences (i.e., highly demanding audiences and scholars). Geotourism activity offers, among other attributes, a better understanding of Earth Sciences, with a focus on conservation and safeguard (Maghsoudi et al. 2019; Veras et al. 2020a, b; Frey 2021). After the recognition of a particular geosite comprising geological, geomorphological, stratigraphic and hydrogeological investigation, the access to fresh surface water is associated with sustainable development (SDGs: 6—essential water; 10—reduced inequalities; 14—life below water, protecting and managing life, and; 15—protecting, promoting and restoring the sustainable use of terrestrial ecosystems). Based on this approach, geotourism can be effective when properly applied in changing the conception of a more committed vision towards geodiversity, biodiversity and the establishment of partnerships with government sectors, stakeholders, and local communities, understood as the main protagonists of change in favour of local progress (Williams et al. 2020; Janssen et al. 2021; Pan et al. 2021).

2 Methodological Procedures

This research is of qualitative-descriptive-exploratory due to the scarcity of work in the area and because it analyses citizens' perceptions of the lotic and lentic ecosystem. The individuals' selection to be interviewed is based on those that are the most experienced in the region as well as those who live close to the water resources. However, due to pandemic scenario was not possible to reach greater number of respondents. Also, being a qualitative approach, the recruitment of respondents should end when theoretical saturation is reached, i.e. when no new properties and dimensions emerge during analysis in terms of observed behaviours and practices (Bloor and Wood 2006). It is expected that this research contributes to the implementation of geotourism within the Brazilian context, aiming to face the challenges of the SDGs 6, 10, 14 and 15.

The research design comprises three stages:

1. A literature review concerning relevant works in the area of lotic environments and sustainable development;
2. The fieldwork which carried out directly with local eight participants. A semi-structured interview script was designed and applied to household, either women or men, using quotes for subsequent content analysis, configuring a descriptive and exploratory methodology (Bardin 1977). The script (Table 1) covers the perception of lotic and lentic ecosystems trough six questions (Minayo 2001; Babbie 2003; Günther 2003; Marconi and Lakatos 2012). The interviews were conducted in homes distributed over a geographical space of 1.7–3 km on so-called vicinal roads or country roads.
3. An audition regarding the available infrastructure at the municipal headquarters, at the Mayor's Hall, as well as on the field. The number of hotels, points of sale of handicrafts, transportation, security, health and sanitation were tracked since these sectors provide indispensable services to the tourism chain. The coordinates through the Global Positioning System (GPS), for the design of a localization map of the research area (Fig. 1), were also recorded.

Table 1 Interview script

Questions
1. The importance of the region's natural water sources
2. Whether you have noticed any change in the water sources since you moved into this place
3. How the maintenance of natural sources is done, and whether you have seen any kind of intervention by the local authorities
4. How the tourist activity in the region is carried out, if they use these natural elements, and whether there is any impact
5. Whether you consider that it should be the local community's responsibility to maintain these natural elements
6. Whether you would do something different if you were responsible for maintaining these water

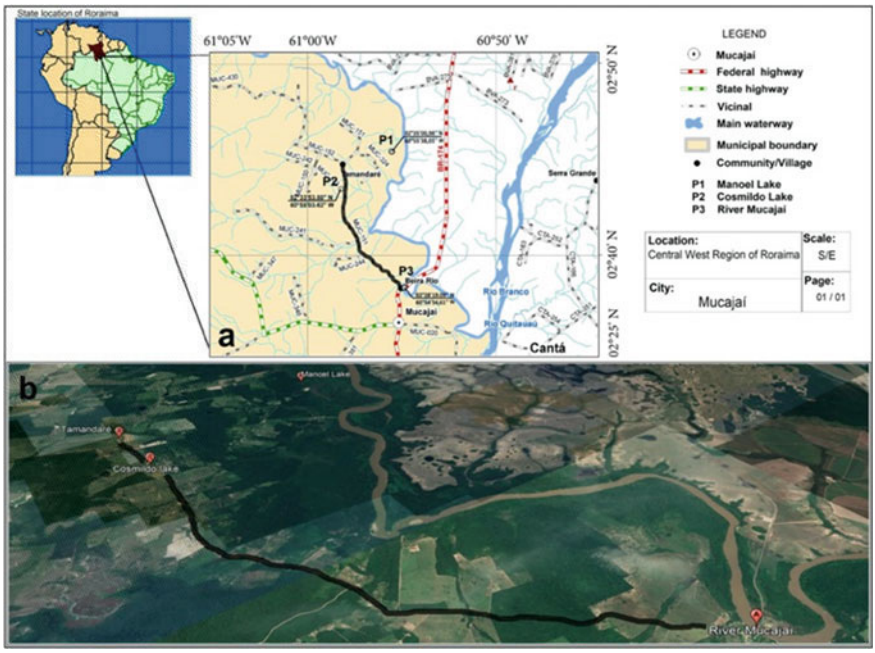

Fig. 1 The geographic location of the Municipality of Mucajaí—Roraima, Brazil. **a** Panoramic aerial landscape view; **b** localisation map and the main water resource the Mucajaí River, Manoel, and Cosmildo Lake

Table 2 Geographical coordinates of the sampling points

Sampling points	Coordinates		Elevation
	Latitude	Longitude	
P 1 Manoel Lake	N 02° 35′ 00.98″	W 60° 55′ 38.01″	79
P 2 Cosmildo Lake	N 02° 33′ 53.80″	W 60° 58′ 03.62″	77
P 3 River Mucajaí	N 02° 28′ 19.09″	W 60° 54′ 54.61″	90

The studied area is located in the Central part of Roraima, the northernmost state in Brazil, well-known for the Amazon Rainforest. The population observed was 18,172 inhabitants, resulting in a demographic density of 1.19 inhabit./km^2. The municipality has a territorial area of 12,351 km^2. According to Köppen climate classification, in its northern area, the altimetric quotas are above 1,000 m of altitude, presenting a tropical wet climate with water deficits around 3–5 months with reduced rainfall (Alvares et al. 2014). The sampling points were chosen because they exhibit expressiveness in the community and more varied uses (Table 2).

3 Results and Discussion

3.1 Analysis of the Interviews with Community Citizens

This section provides the analysis and interpretation of the eight interviews conducted in the field regarding the citizens' perception of lotic and lentic ecosystems based on the SDGs 6, 10, 14, and 15. The respondents are mostly males (n = 6), with middle school level (n = 4), with a mean of 60 years old (Min = 37; Max = 73), living in the region for an average of 41 years (Min = 33; Max = 51) and being agricultural workers (n = 6) (Table 3).

In each household, it was requested that respondents shared their perception about lotic ecosystems. Table 4 presents the interview results and correspondent responses to better illustrate.

Regarding the importance of natural resources, local citizens believe that rivers and lakes are essential to their livelihoods, which highlights their awareness of the importance to safeguard and protect this ecosystem. On the other hand, this resource is ensured by the Federal Constitution of 1988 (Brazil 1988; Hasan et al. 2021). The primary need for safe sanitation is assessed, which would improve resilience and, in turn, lead to a greater and more constant interest in SDG 6.

About the role of the municipal management, a lack of actions and investments are identified regarding basic sanitation to improve the quality of life of its citizens, specifically those located further away, which would partly allow the achievement of sustainability in compliance with the Global Agenda (Maasri et al. 2021). The new legal framework for basic sanitation states within its main focuses: (i) A target of 99% of the population with access to drinking water; (ii) a target of 90% of the population with access to sewage collection and treatment; and (iii) actions to reduce water waste and use rainwater. In the Amazon region it rains a minimum of 471.3 mm/month (Barni et al. 2020; Brazil 2020). The lack of basic sanitation in most remote locations results in many occurrences of diseases due to lack of drinking water. These remote regions are the most vulnerable to the impacts of

Table 3 Respondents' sociodemographic characteristics

Respondent	Sex	Age	Education level	Residence in the region (Years)	Occupation
1	Female	65	Elementary school	33	Agricultural worker
2	Male	41	Middle school	41	Agricultural worker
3	Female	67	Elementary school	40	Housekeeper
4	Male	72	Middle school	51	Agricultural worker
5	Male	67	Elementary school	40	Agricultural worker
6	Male	73	Middle school	51	Agricultural worker
7	Male	51	University	37	Teacher
8	Male	44	Middle school	33	Agricultural worker

Table 4 Questions and correspondent respondents' quotes

Questions	Quotes
The importance of the region's natural water sources	"*It is very rich for us who live here, the land that has a water source adds value to the place, it provides life, sustenance, and entertainment for all. Here we have an association and we all have the concern of not letting the insecticide contaminate the water of the river and the lake. We often fish from these water sources… and our families are all our wealth*" (Respondent 4) "*It is essential for us human beings, for the animals and even for the forests and plants that we have in the region*" (Respondent 5)
Whether you have noticed any change in the water sources since you moved into this place	"*We have observed that these rivers and lakes have decreased in volume year by year. Exactly after the dry season*" (Respondent 5) "*We noticed a change at the top of the water. At that time, few and almost no one frequented Manoel Lake … because they thought that the dark water hid some danger*" (Respondent 6)
How the maintenance of natural sources is done, and whether you have seen any kind of intervention by the local authorities	"*Maintenance should be done on private property to improve the structure that the producer has, but we do not get from the government. The municipality has not done much …*" (Respondent 2) "*The Residents' Association does the maintenance, they get together and on a leisure day they clean up the rubbish (plastics, falling branches and others)*" (Respondent 3)
How the tourist activity in the region is carried out, if they use these natural elements, and whether there is any impact	"*Tourist activity is practically non-existent in these environments… What we see in the region are bicycle rides on trails and there is no participation in the freshwater springs*" (Respondent 5) "*Here in this region, in terms of rural tourism, there is almost zero, but I heard that the municipality is working to bring resources to invest in tourism, especially during this time of pandemic…*" (Respondent 2)
Whether you consider that it should be the local community's responsibility to maintain these natural elements	"*If the community had the support of the authorities, we could do it ourselves, with canoes and boats, to go around and see what they are doing wrong*" (Respondent 1) "*The community knows everything, the best seasons to treat the environment. And there*

(continued)

Table 4 (continued)

Questions	Quotes
	are many young people here who can make a difference in the future" (Respondent 8)
Whether you would do something different if you were responsible for maintaining these water sources	"*These aquifers are the patrimony of all of us citizens. I would raise awareness among everyone, up to the authorities. What mankind needs to do is to be more careful with their attitudes and waste regarding nature*" (Respondent 5) "*I would form a team to assess and look after the river and lake more closely, but those who come from far away have to pay, just a little, but this is for us to organise trips and fishing*" (Respondent 2)

polluted waters and waste disposal, e.g., insecticide chemicals and This represents a significant threat across the planet to the health of humans, biodiversity, and the environment, ultimately ending up in the seas, which is contrary to SDG 14—life in water (Debrah et al. 2021). Awareness of water importance was reported through the interviews, as well as the dependence on water for everything, and the perception of climate change, excessive heat in the summer period, and/or even in the rainy period. Although these citizens are aware of the seriousness of human action, they do not stop setting fire to their lands, which they claim to be an ancestral practice, arguing that the ashes would make the land more fertile. They reiterate the importance of buying land with watercourses because this kind of land is more valued.

While respondents do not take responsibility for the changes identified in the lakes, they perceive changes in the vegetation of the water sheet through the growth and invasion of aquatic plants, found unanimous. As mentioned by Damtew et al. (2021), vegetation is the result of anthropic stressors and climate change, emerging with floating and rooted leaves, part of the ecosystem, and playing a key role in neutralizing pollutants, regulating the production of contaminants, oxygen generation, and the carbon cycle. However, respondents know and describe the vegetation, but are unaware of the reason for the ecosystem's defensive reaction. It is worth to note that experimental projects for the implementation of geotourism activities are welcome in this territory, even if they start with a short duration itinerary.

The perception about the reduction and colour of the water during the dry season shows that citizens, even in remote areas, feel the climate change and are among the most affected. The report of plants on the lamina water signals a probable change in and the colouration is influenced by the vegetables, animals, minerals, tannins and algae in these surface water bodies such as lakes (Ghosal et al. 2020; Abel et al. 2021).

The interviewees were unanimous when they stated that there is no maintenance of natural sources by the local authorities, which do therefore reflect the neglection by the public authorities. In this sense, waters and forests are assets that belong to

the Union and the state, and it is not up to the municipalities to legislate on these resources, according to the Brazilian Forest Code (Brazil 2012). The states regulate their use, through authorizations and concessions. Thus, the initiative of the sensitized community preserves the river and lake, and meets locally, in part, the SDG 15—Ensure and Conserve the Aquatic Ecosystem.

Regarding the tourism activity in the region, one interviewee mentioned that the word tourism is known to all, but not in an alternative way, yet, in this locality. This denotes the citizen's understanding that for every activity an investment must be made, with training and necessary infrastructure to welcome the visitor. It is therefore assumed that the natural will of the community must be in harmony with all relevant stakeholders, which include the leaders, municipal planning and the private sector. However, for other respondents, tourism is limited to walks and physical itineraries, bathing in the river, and taking pictures to send to friends, and this is their understanding of local tourism. The expressive set of scenic landscapes that contemplate the hydric resources and the exploitation of these environments can be worked within what the tripod of the segment advocates, i.e., transportation, lodging, and operationalization of the trip by a travel agent. From this understanding, sustainable tourism should take advantage of environmental resources, respect the authenticity of local culture, ensure long-term local economic sustainability and ensure income opportunities for the host community, and in this aspect also contributes to the mitigation of poverty (UNWTO 2020).

Most of the respondents are fully aware that the river and the lakes need maintenance, which has not been conducted by the public authorities, and that everyone needs to do something for the nature that serves them, e.g., awareness-raising campaigns. In this regard, it is worth highlighting everyone's efforts, within their possibilities, to avoid that waters to be the target of disposable waste, as water is considered a finite and vulnerable resource. If there is a terrible misuse of these resources, it will be translated into a series of complications for humanity, and this is a concern of the, which highlights water security as a global concern (Waseem 2021).

Finally, a consensus among the respondents is identified in relation to the investments in infrastructure and training to attract people to the region. This consensus is based on good planning practices accompanied by a specialist for the development of tourism in the location. Therefore, all this unanimity goes through good planning practices accompanied by a specialist for the development of geotourism in the locality.

3.2 Study Area Assessment Regarding Infrastructures for the Implementation of Geotourism Activity

Visits to natural environments have become increasingly pursued. Geotourism presents itself as a sustainable alternative because it is not seasonal and, to check the specificness of these abiotic resources, the Mucajaí River, the Cosmildo Lake, and

the Manoel Lake are available for geological interpretation, verification of importance and multiple uses, which include leisure and recreation activities, landscaping, diving, fishing and boat trips. Looking at these open-air laboratories from a geomorphological point of view reveals an opportunity to fulfil the Global Agenda goals. The diversity of freshwaters can be found in Fig. 2.

3.2.1 Mucajaí River

The geological and structural framework of the region allows describes Mucajaí River, a lotic system, as a perennial river of particular notoriety, as it not only benefits the people who live in its surroundings but also offers various advantages, especially for agriculture, sustains the unique biodiversity elements in its ecosystem, and is also a cultural and geotouristic element because of its waterfalls. Its location is characterized as feature on the Guiana Shield, of Precambrian origin, formed by a set of lineaments with NE-SW direction extending from a part of the Amazonas State to the proximities of Paramaribo and the Republic of Guyana (Feitoza et al. 2007). With its sinuous geomorphology, the Mucajaí River is about full of natural elements that promote the geotourism scenarios in its middle and upper course, such as the waterfalls known as Prego; da Lata; do Funil; dos Índios; Querosene; and do Arromba. Throughout its course, it is located in a forest region (Ferreira et al. 1988; Veras 2014; Santos et al. 2018). It is representative of the rich natural heritage and can provide a unique, authentic, and unforgettable experience to the Geotourist, in addition to the high diversity of freshwater fish (e.g., Hoplias

Fig. 2 **a** Mucajaí River, belonging to the lotic ecosystem, is the main water resource. **b** Cosmildo Lake and **c** Manoel Lake belong to the lentic ecosystem, surrounded by a terrestrial system of natural vegetation, aquatic macrophytes and small communities (i.e., fish and frogs)

malabaricus; Traira (Wolf fish); Boulengerella ocellata—Bicuda; *Semaprochilodus* spp.—Jaraqui; Hemiodus spp.—Piau; Colossoma macropomum—Tambaqui; Pygocentrus spp.—Piranha).

3.2.2 Manoel Lake

This lake is located at geographical coordinates N 02° 35′ 00.98″ and W 60° 55′ 38.01″ and elevation 77 m above sea level, in the central region of Roraima, in the municipality of Mucajaí. Access is via a side road, known as RR 325 or Tamandaré. With transparent waters, the lake has a depth of 6 m, and 40 cm at its shallowest point. As a true phenomenon of nature, it contributes to agriculture and other economic activities in the region. The landscape around the lake is rich in species, formed by an almost untouched riparian forest with intense green colours. Belonging to the lentic ecosystem, the lake nourishes the biodiversity contained in its waters and terrestrial surroundings, with algae vegetation and endemic insects, and offers specific fish species: Semaprochilodus spp.—Jaraqui; *Hemiodus* spp.—Piau; Colossoma macropomum—Tambaqui. Its enchanting tropical scenery of waters and beauty in a pure state of conservation invites the tourist into taking a boat ride and contemplating nature.

3.2.3 Cosmildo Lake

Geological environment belonging to the Guiana Shield and, finally, to the Central Amazon. It has a direct relationship with the Mucajaí River, the main water resource in the region. Access to the lake is via the Highway RR 325, approximately 30 km away, and can be found according to the geographical coordinates N 60° 57′ 55.89″ and W 60° 57′ 55.89″. Its elevation is 90 m above sea level. The name of the geo-resource is a tribute to the owner of the farm where it is located. The physiographic characteristics are preserved and it is suitable for visits. The landscape scenery in its waters allows boat trips and fishing in favourable seasons, and geotourism activity can be implemented.

3.3 Tourism Infrastructure

The set of implementations of the physical structure and basic services that support the development of tourism enable dynamism for this territory's vocation for tourism. The Urban Equipment available is presented in Tables 5 and 6.

Table 5 Equipment for tourism logistics in Mucajaí-RR

Hotels (beds in HU)	Access infrastructure (roads)	Transportation	Basic sanitation
4 hotels 32 HU's, 40 beds	BR 174 (federal highway) RR 325, 205 and country roads 6, 11	Cooperatives for alternative transportation, Cooperative-Cootam, Macuxi Motorbike Taxi Association Road transportation	Only at houses in urban areas, and it counts with 3 water treatment stations, with 175,000 l

Source Municipal Secretary of Culture, Sports and Tourism of Mucajaí-RR. *UH = Housing units

Table 6 Equipment and services

Theatre	Security	Health	Centre for the commercialization of handcrafted products
1 Centre for conventions 1 Area for the performance of the play 'Passion of Christ' 10,000 m^2	1 Department of the Military Police	2 Health clinics 1 Hospital	3 Basket, wood and bio jewellery stores

Source Municipal Secretary of Culture, Sports and Tourism of Mucajaí-RR

4 Final Remarks

The challenge of universalising the sustainable use of water is a contemporary frontier to be overcome regarding the Global Agenda 2030, based on the premise that humans are the main responsible for the success or failure in the protection of water resources. The plenty of ecosystem services provided by water resources must be stated: store freshwater, provide fishing resources and favour the well-being of citizens with leisure and educational recreation, while considering the interpretation carried out by geotourism. Thus, in the face of so many advantages, it has been a source of prosperity for all living beings, legitimising the objectives of the Global Agenda with the challenge of improving management in remote places (Maasri et al. 2021).

Lastly, it is worth mentioning that geotourism is a process for everyone's participation, in which citizens, water resources management authorities, national and local territories should consider the institutional and legal frameworks, while the numerous sectors that move the economy must be committed to guaranteeing a sustainable water resource. Among the strengths of the SDGs 6, 10, 14 and 15, the goals that stand out are those advocating for harmony and integration not only with environmental dimensions, but also with people, prosperity, the planet, peace, and partnership. This work shows that when asked about the importance of freshwater and its uses including geotourism, citizens reveal that they are committed to

preservation, thus showing the need to receive attention from authorities and investments in infrastructure, and training for managers.

This work shows that when asked about the importance of freshwater and its uses including geotourism, the local community reveals to be committed to preservation, thus showing the need to receive attention from authorities and investments in infrastructure, and training for managers.

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