

Spatial modeling for the protection of waterways in the Quinsaloma canton, Los Ríos, Ecuador

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Abstract: This research aims to spatially model the protection of watercourses in Quinsaloma canton (Los Ríos, Ecuador), for the integrated management of water resources. A mixed-methods approach was adopted, combining quantitative and qualitative techniques, including surveys of 90 residents and interviews with community leaders. The results show that the Calabí River, the main water source in the region, has suffered degradation in both water quality and quantity due to anthropogenic activities such as agriculture, mining and industry, alongside the impacts of climate change. 51.1% of respondents stated that the river water exhibited marked changes in colour, odour and taste, which indicates deterioration of its organoleptic properties. Furthermore, 87% of participants identified agriculture and mining as the primary pollution sources, consistent with similar studies conducted in other regions of Ecuador. Climate change was also recognized as a critical factor; 86.6% of respondents attributed the drying-up of seasonal creeks and small streams to this phenomenon. This study proposes strategies including riparian reforestation and public training on sustainable practices. Finally, it highlights the need for greater citizen engagement and commitment from local authorities to ensure the sustainability of water resources.

Key words: water management; climate change; anthropogenic activities

1 Introduction

Water resources management and conservation have become one of the most critical challenges worldwide, especially in regions where water demand exceeds available supply. According to Vivanco et al. (2022), the water crisis is a phenomenon affecting millions of people globally; approximately six million inhabitants face severe water scarcity due to overexploitation, pollution and climate change. This situation is exacerbated in developing countries, where inadequate policies and the expansion of agricultural and industrial activities have led to the degradation of water bodies (Loaiza et al., 2022a). In Latin America, for instance, deforestation and river pollution have triggered a water crisis that impacts not only water availability but also food security and public health (FAO, 2013).

Ecuador possesses abundant water resources; nevertheless, uneven distribution and river pollution have caused substantial problems in multiple regions. According to Nieto-Cañarte et al. (2020), river pollution in Ecuador is mainly attributed to industrial wastewater, urban sewage and mining exploitation, which has resulted in the degradation of aquatic ecosystems. Furthermore, climate change has exacerbated these issues. Longer droughts and extreme climate events are affecting water availability (Lozano-Mendoza et al., 2019). In this context, Los Ríos Province, which is known for its extensive water bodies, faces similar challenges. This is especially true in cantons such as Quinsaloma, where the absence

of research and conservation strategies has led to the degradation of watercourses (GAD-Quinsaloma, 2020).

Quinsaloma canton, located in Los Rios Province, relies heavily on the Calope, Chipe and Minoape rivers for agricultural, tourist and domestic water use. Nevertheless, logging, mining and the impacts of climate change have caused reductions in both the quality and quantity of these water resources (Guerrero et al., 2024). In addition, low public awareness and limited intervention from local authorities have worsened the situation, which creates the need to implement conservation and protection strategies for watercourses in the region.

In this regard, this study aims to spatially model protection zones for the watercourses of Quinsaloma canton, to develop an Integrated Water Resources Management Plan (PGIRH). This plan intends not only to diagnose the current status of water resources but also to propose conservation and protection strategies that ensure the long-term sustainability of these resources. To achieve this, surveys and interviews with local residents were conducted, alongside geographic data analysis using geomatic tools, to identify the most vulnerable areas and propose mitigation measures, as recommended by Nieto-Cañarte et al. (2024).

The relevance of this study lies in its integrated approach, which combines public perception with technical-scientific analysis to propose viable and sustainable solutions. Furthermore, this work contributes to the existing literature on water resources management in tropical regions, where the interaction between human activities and climate change has created unique challenges requiring adaptive and participatory solutions (Nieto-Cañarte et al., 2025). Lastly, the findings of this research are expected to serve as a foundation for future studies and public policies aimed at water resources conservation in Ecuador and other regions with similar conditions.

2 Theoretical framework

The water crisis is a global phenomenon that has been extensively documented by international organizations such as UNESCO and FAO (2013). According to UNESCO (Vivanco et al., 2022), more than 1.1 billion people in developing countries lack access to safe drinking water, and it is estimated that by 2025, approximately 1.8 billion people will live in regions suffering from absolute water scarcity. This crisis stems from a combination of factors, including population growth, overexploitation of water resources, pollution and the impacts of climate change (Nieto-Cañarte et al., 2023). In Latin America, deforestation and the expansion of the agricultural frontier have worsened the degradation of water bodies, resulting in reductions in both the quality and quantity of available water resources (Guerrero et al., 2020).

Integrated Water Resources Management (IWRM, GIRH) has emerged as a key strategy to tackle the global water crisis. According to Islam and Gilbert (2025), IWRM promotes the coordinated management of water, land and other related resources, aiming to maximize social and economic welfare without compromising ecosystem sustainability. This approach has been adopted by several Latin American countries, where water governance has been hampered by inadequate policies and the privatization of water resources (Sanabria et al., 2022). In Ecuador, IWRM was enshrined in the 2008 Constitution, which recognizes the right of indigenous communities to manage and benefit from natural resources within their territories (Loaiza et al., 2022b).

Climate change is one of the major factors affecting the availability and quality of water resources. According to the IPCC Fifth Assessment Report (2014), climate change has altered precipitation patterns and increased the frequency of extreme climate events such as droughts and floods. These changes have exerted a substantial impact on aquatic ecosystems, reducing water availability and degrading water quality (UN, 2019). In Ecuador, climate change has aggravated water scarcity in regions such as Manabí Province, where deforestation and soil degradation have reduced soil water retention capacity (Lozano-Mendoza et al., 2024).

Riparian vegetation cover plays a critical role in water resources conservation. According to Huang et al. (2025), riparian forests function as natural filters, trapping sediments and nutrients that would otherwise pollute water bodies. Furthermore, these forests help sustain river discharge during dry seasons, which is essential for the survival of aquatic ecosystems and the communities dependent on them. In Ecuador, reforestation using native species has been proposed as a strategy to protect water resources in regions such as Esmeraldas Province, where deforestation has resulted in the loss of water sources (Nieto-Cañarte et al., 2023).

Anthropogenic activities such as agriculture, mining and industry constitute the primary sources of water body pollution. According to Han and McCreary (2001), these activities produce chemical and organic wastes that alter water quality and impair aquatic biodiversity. In Quinsaloma canton, agriculture and mining have been identified as the main pollution sources of the Calabí River. This has caused water quality degradation and the loss of intermittent creeks and small streams (GAD-Quinsaloma, 2020). Furthermore, inadequate treatment of industrial wastewater has aggravated these problems, bringing adverse impacts on the health of local communities (Liu et al., 2025).

Spatial modelling is a key tool for the planning and management of water resources (Moura et al., 2025). According to Nobre and Cirilo (2024), Geographic Information Systems (GIS) enable the analysis of variables such as lithology, slope and vegetation cover, which is essential to identify priority areas for the conservation and restoration of water bodies. In the case of Quinsaloma, the application of geomatic tools allows the delineation of protection zones for watercourses, which is fundamental for developing an IWRM plan.

Territorial planning is an essential component of water conservation. According to Zhou et al. (2021), hydrological zoning makes it possible to identify sensitive areas requiring intervention to improve water yield and reduce soil erosion. In Ecuador, territorial planning has been integrated into the Territorial Ordering Plans (PDOT), which contain strategies for water resources conservation and mitigation of climate change impacts (GAD-Quinsaloma, 2020). Such strategies include riparian reforestation, establishment of protection buffers and capacity-building for all stakeholders.

3 Methodology

This research adopted a non-experimental, exploratory and descriptive design with a mixed-methods approach combining quantitative and qualitative methods. This design enables the analysis of the current status of water resources in Quinsaloma canton, Los Ríos Province, and the proposal of conservation strategies based on empirical data and public perception (Schaperow et al., 2021). The study was carried out in three main phases: diagnosis, delineation of conservation areas, and design of protection strategies.

3.1 Study location and study area

The study was conducted in Quinsaloma canton, located in Los Ríos Province, Ecuador (Figure 2). The region features a subtropical climate, with a total population of 16,476 inhabitants (7,849 females and 8,627 males) according to data from the National Institute of Statistics and Censuses (INEC, 2010). The study area covers the influence zones of the Calabí River, the primary water source for agricultural, tourist and domestic water use in the region (GAD-Quinsaloma, 2020). The geographic coordinates of the canton are 0°56'56"N, 1°31'41"S, 1°0'05"W and 1°19'47"E.

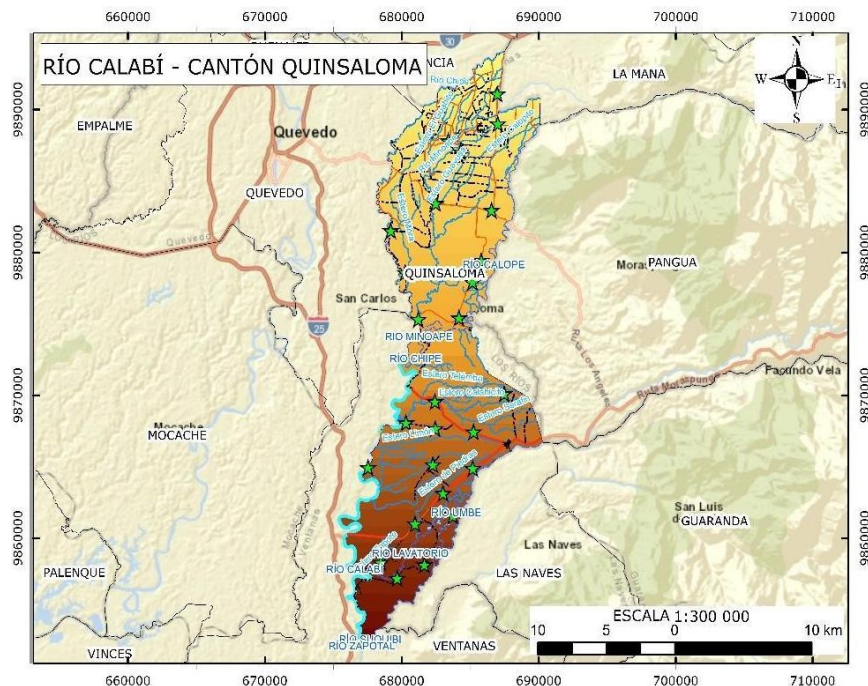


Figure 1. Geographic location of the study area

Source: Own elaboration.

3.2 Type of research

This is an exploratory study, as it addresses an issue that has not been fully analyzed within the context of Quinsaloma canton. In addition, it is documentary research, because it relies on the review of scientific literature, regulations and secondary data provided by institutions including the National Institute of Statistics and Censuses (INEC), the Ministry of Environment, Water and Ecological Transition (MAATE), and the Decentralized Autonomous Municipal Government of Quinsaloma canton (GAD-Quinsaloma). Lastly, it is diagnostic research, as it aims to identify and characterize the current status of water resources in the region (Jia and Zhang, 2025).

3.3 Research methods

Three main methods were used for data collection and analysis: Inductive-Deductive Method: This method allowed the study to start from specific observations of the water situation in Quinsaloma to draw general conclusions regarding the need for the conservation and protection of watercourses; Analytical-Synthetic Method: It was applied to break down the collected information into smaller components, analyse these components and subsequently integrate them into a coherent whole to fully understand the problem; Bibliographic Method: Secondary sources including scientific articles, theses, technical reports and regulations related to water resources management and environmental conservation were reviewed (Khan et al., 2025).

3.4 Sources of information collection

Information sources were divided into primary sources and secondary sources. Primary sources: Ninety surveys were applied to the population of the sectors within the study area (1,692 inhabitants), alongside five interviews with community leaders from the settlements of El Achotillo (307 inhabitants), El Gualbito (300 inhabitants), Fruta de Pan (350 inhabitants), Loma de Coco (455 inhabitants) and El Cerrito (280 inhabitants). The surveys were designed with Likert-scale questions to measure public perception regarding water quality and water conservation. The interviews were structured to obtain detailed information on the water-resource situation and human activities that impact these resources. Secondary sources: Data were collected from institutions including INEC, MAATE and GAD-Quinsaloma, as well as cartographic

information from the Military Geographic Institute (IGM) and the Quinsaloma Development and Territorial-Ordering Plan (PDOT). Landsat 8 satellite images were also used to analyse vegetation cover and water bodies across the region (Bazzett et al., 2025).

3.5 Research instruments

The main research instruments used were: Surveys: Ninety surveys were administered, each containing 20 questions, designed to measure public perception of water quality, polluting activities and the importance of water conservation. Interviews: Five semi-structured interviews were conducted with community leaders to obtain qualitative information on the water-resource situation and conservation needs. Direct Observation: An in-situ analysis of water bodies and the activities affecting them was carried out, complemented by the review of maps and geographic data (Choulga et al., 2024).

3.6 Data analysis

The quantitative survey data were analyzed using statistical tools: spreadsheets (Microsoft Excel) were employed for data tabulation, and the statistical software package (SPSS) for graphical representation of results. For the qualitative analysis of interviews, the content-analysis technique was applied to identify patterns and recurring themes related to water conservation (Koit et al., 2025).

In addition, geomatic software (ArcGIS) was used to delimit conservation areas through hydrological zonation. This process included the analysis of variables such as lithology, slopes, land-use types and water bodies (Figure 2). Weighting of these variables allowed the identification of priority areas for the conservation and restoration of water bodies (Shen et al., 2020).

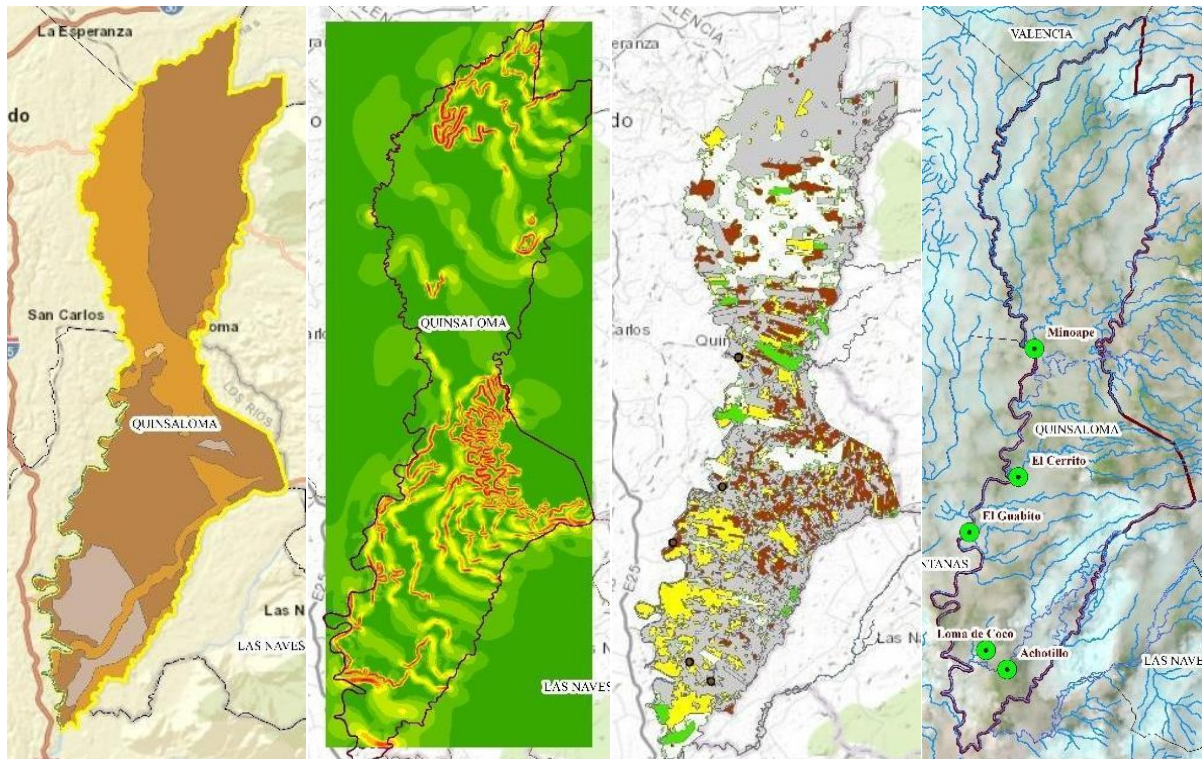


Figure 2. Map of lithology, slopes, land-use types and water bodies

Source: Own elaboration

3.7 Proposal for conservation strategies

Based on the obtained results, an Integrated Water-Resources Management Plan (PGIRH) for the canton of Quinsaloma was designed. This plan comprises strategies and activities framed within four strategic sectors: agriculture,

industry, electricity and tourism. The proposed activities include riparian reforestation, the implementation of wastewater-treatment systems, and community training on sustainable practices (GAD-Quinsaloma, 2020).

3.8 Human resources and material resources

The research was supported by professionals in environmental engineering and geography, alongside advanced technology including GPS receivers, cameras and specialized software (Microsoft Office, SPSS, ArcGIS). In addition, bibliographic resources and regional and global scientific databases were used for the literature review (Malagó et al., 2021).

4 Results and discussion

The results of the surveys and interviews conducted in the canton of Quinsaloma reveal that local residents perceive a decline in the water quality of the Calabí River, mainly attributable to anthropogenic activities such as agriculture, mining and industry (Figure 3). These findings are consistent with studies carried out in other regions of Ecuador, such as Cuenca, where Sanabria et al. (2022) found that river water quality is affected by wastewater discharges and agricultural activities. In Quinsaloma, 51.1% of respondents stated that the water of the Calabí River has undergone significant changes in colour, odour and taste, which suggests deterioration in its organoleptic properties. This phenomenon aligns with the findings reported by Nieto-Cañarte et al. (2015) in Quevedo, where the absence of wastewater treatment has led to reduced water quality.

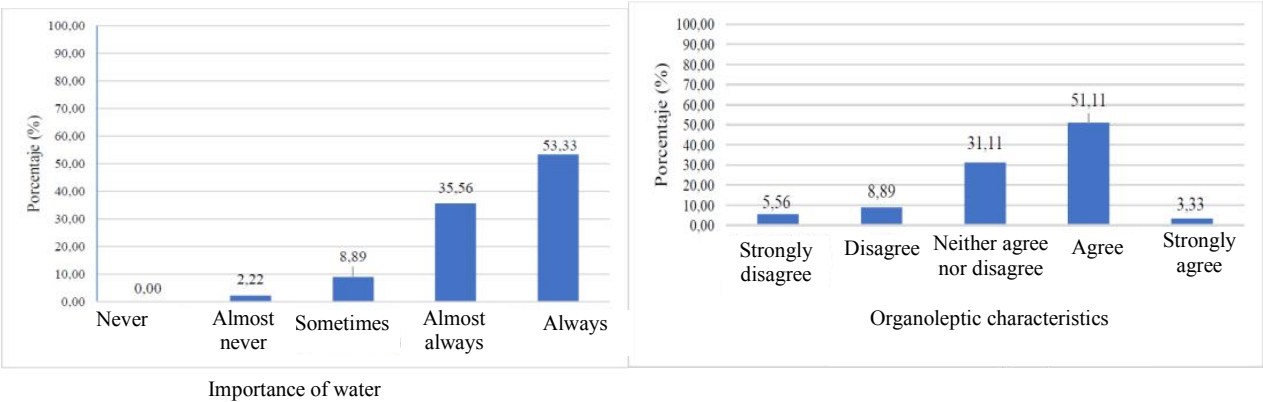


Figure 3. Surveys on citizens' perceptions of water quality

Source: Own elaboration.

Anthropogenic activities, especially agriculture and mining, have been identified as the main pollution sources in the Calabí River. According to Malagó et al. (2021), these activities produce chemical and organic wastes that degrade water quality and impact aquatic biodiversity. In Quinsaloma, 87% of respondents regarded agriculture and mining as the primary polluting activities (Figure 4), which is consistent with the findings of Loaiza et al. (2022a) for the Santa Rosa River, where banana cultivation and waste burning have caused high pollution levels. Furthermore, a lack of public awareness and limited intervention by local authorities have exacerbated these issues, as noted by Jia and Zhang (2025).

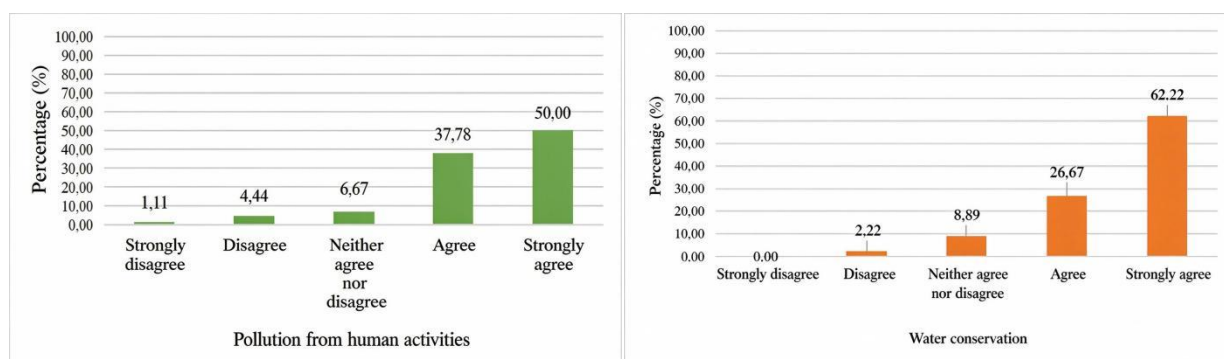


Figure 4. Survey results on the impact of anthropogenic activities

Source: Author's own elaboration.

Climate change has been identified as one of the major factors affecting the availability and quality of water resources in Quinsaloma. According to the IPCC Fifth Assessment Report (2014), climate change has altered precipitation patterns and increased the frequency of extreme climate events such as droughts and floods. In Quinsaloma, 86.6% of respondents believed that climate change is responsible for the disappearance of wetlands and streams (Figure 5). This is consistent with the findings of Nieto-Cañarte et al. (2023) in the Ecuadorian Amazon, where climate change has exacerbated water scarcity issues. In addition, rising temperatures and declining precipitation have adversely affected water availability in the region, as reported by Huang et al. (2025) in their study on water availability in Latin America.

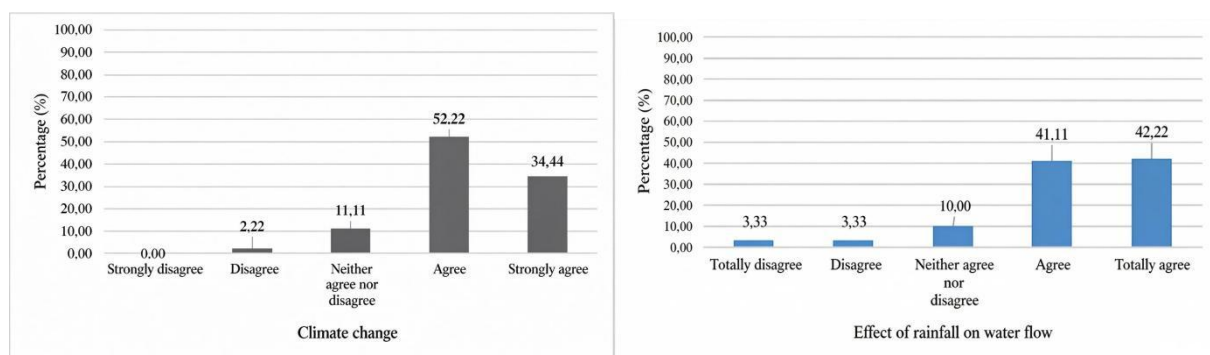


Figure 5. Surveys on climate change and its impact on water resources

Source: Prepared by the author.

The lack of intervention by local authorities and low citizen participation in water resources conservation have been identified as factors exacerbating the problem in Quinsaloma. According to Loaiza et al. (2022b), citizen participation is essential for the successful implementation of conservation strategies, as it fosters public awareness and commitment among residents. In Quinsaloma, only 2.2% of respondents stated that they had received training on the impacts of anthropogenic activities on water bodies, indicating insufficient commitment from local authorities (Figure 6). This phenomenon aligns with findings reported by Alarcón (2019) in the Galápagos Islands, where inadequate ecological and political oversight has resulted in inefficient water resources management.

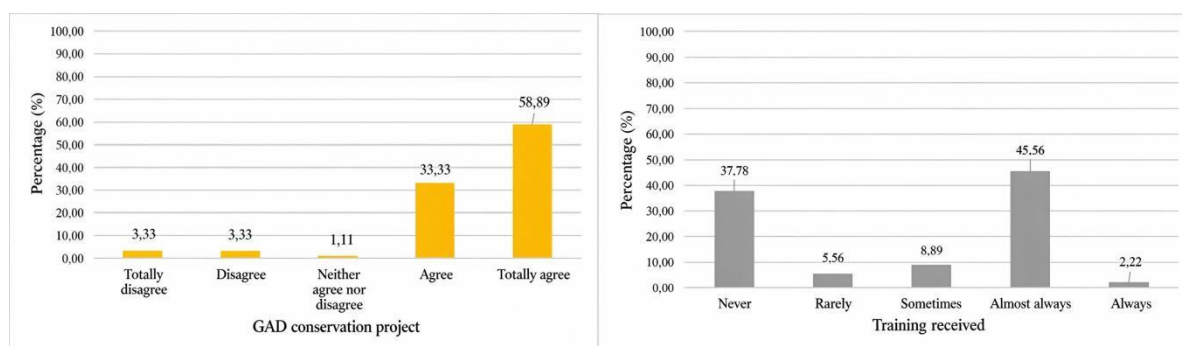


Figure 6. Surveys on conservation strategies and the role of local authorities

Source: Own elaboration.

The proposed Integrated Water Resources Management Plan (IWRMP) for Quinsaloma includes strategies such as riparian reforestation, the deployment of wastewater treatment systems, and community training on sustainable practices. These strategies align with the recommendations of Nieto-Cañarte et al. (2024), who argue that hydrological zoning and reforestation constitute key instruments for water resource conservation. Furthermore, technological tools such as ArcGIS have enabled the identification of priority conservation areas, which is essential for delivering effective strategies (Figure 7), as noted by Sanabria et al. (2022) in their study of water erosion within the upper Sibimbe River basin.

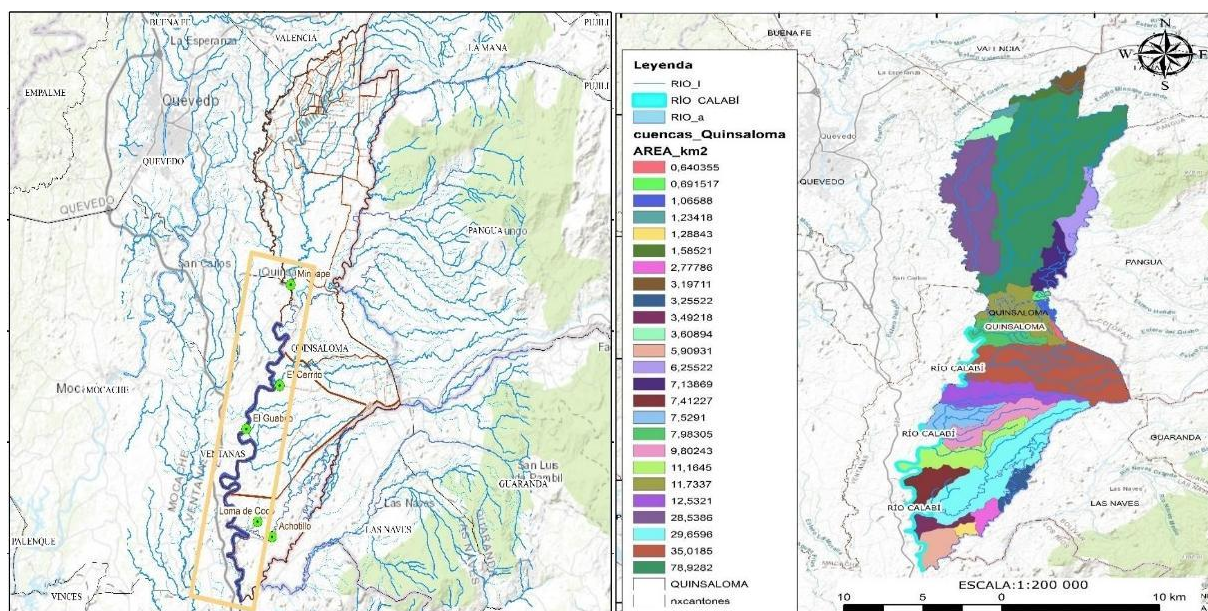


Figure 7. Proposal for an integrated water resources management plan

Source: Own elaboration.

5 Conclusion

The diagnostic assessment conducted in Quinsaloma canton reveals that the Calabí River constitutes the primary water source supporting agricultural, tourism and domestic water use in the region. Nevertheless, both its water quality and availability have declined markedly owing to anthropogenic activities including agriculture, mining and industry, alongside the impacts of climate change. In Quinsaloma, 51.1% of respondents stated that Calabí River water has undergone substantial changes in colour, odour and taste, indicating deterioration in its organoleptic properties.

Anthropogenic activities, particularly agriculture and mining, have been identified as the main pollution sources in the Calabí River. A total of 87% of respondents regarded these activities as the primary contributors to water pollution. In addition, low public awareness and limited intervention from local authorities have exacerbated these problems.

Climate change has been identified as one of the major factors affecting the availability and quality of water resources in Quinsaloma. A total of 86.6% of respondents considered climate change responsible for the drying up of wetlands and streams. In addition, rising temperatures and reduced precipitation have adversely impacted water availability in the region.

The proposed Integrated Water Resources Management Plan (IWRMP, P-GIRH) for Quinsaloma includes strategies such as riparian reforestation, deployment of wastewater treatment systems, and community training in sustainable practices. Furthermore, the application of technological tools such as ArcGIS has enabled the identification of priority conservation areas, which is essential for the delivery of effective strategies.

Insufficient intervention by local authorities and low public participation in water resource conservation have been identified as factors exacerbating the problems in Quinsaloma. In Quinsaloma, only 2.2% of respondents stated that they had received training regarding the impacts of anthropogenic activities on water bodies, which suggests a lack of commitment from local authorities.

It is recommended that further studies be carried out to include a comparative analysis of the evolution of climatic variables and water quality across different periods. In addition, it is essential to implement environmental education programmes that engage the community in water resource conservation. Lastly, the formulation of public policies to promote sustainable water management is suggested, grounded in the principles of Integrated Water Resources Management (IWRM).

Conflicts of interest

The author declares no conflicts of interest regarding the publication of this paper.

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