

## Development Of Environmental Sustainability Indicators For The Ecosystem Of Lagoon Yambo, Ecuador.

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### ABSTRACT

Yambo Lagoon, located in the province of Cotopaxi, Ecuador, is a high-altitude aquatic ecosystem exposed to increasing anthropogenic pressures derived mainly from tourism and agricultural activities. These pressures threaten its ecological integrity and highlight the need for context-specific tools to support environmental management and decision-making. This study aimed to develop a set of environmental sustainability indicators adapted to the socio-ecological conditions of the Yambo Lagoon, using the Pressure–State–Response (PSR) framework. A mixed-methods approach was applied, combining quantitative data obtained through structured questionnaires administered to residents and visitors, and qualitative information derived from semi-structured interviews with local stakeholders. Descriptive statistical analysis and qualitative content analysis were conducted using SPSS v.26 and ATLAS.ti, respectively. The results indicate a high level of environmental awareness among respondents, with 87% recognizing the ecosystem’s characteristics and mass portion identifying tourism and agricultural activities as the main sources of environmental pressure. Fifteen key variables were identified across social, economic, environmental, and institutional dimensions. Pressure indicators revealed intensive land use, agrochemical application, and increased tourist flows as dominant stressors, while state indicators reflected deterioration in soil quality, water resources, and biodiversity. Response indicators showed limited effectiveness of existing management actions. The study concludes that the proposed indicator system provides a practical and replicable tool for monitoring ecosystem sustainability and emphasizes the need to strengthen environmental education, participatory governance, and integrated management strategies to ensure the long-term conservation of the Yambo Lagoon

**Keywords:** ecosystem, anthropogenic pressure, environmental management, Pressure-State-Response model, environmental value

### INTRODUCTION:

Aquatic ECOSYSTEM in the Andean region play a fundamental role in biodiversity conservation, water regulation, cultural identity, and local economic development (García, 2025). In Ecuador, highland lagoons are particularly valuable due to their ecological functions and their growing importance as tourist destinations. However, these ECOSYSTEM are increasingly exposed to anthropogenic pressures associated with unplanned tourism, agricultural expansion, changes in land use, and insufficient environmental governance, which collectively threaten their ecological integrity and long-term sustainability (Ghanima Amin, 2025); (Logic Clean, 2025).

The Yambo Lagoon, located in the province of Cotopaxi, represents a strategic ecosystem within the central Ecuadorian highlands. In recent decades, the lagoon has experienced a progressive intensification of human activities, particularly tourism and agriculture, resulting in landscape degradation, accumulation of solid waste, water contamination, loss of aquatic habitats, and soil erosion. Similar processes have been documented in other Andean and lacustrine ECOSYSTEM, where the absence of

integrated planning and effective environmental management has led to significant ecological deterioration (Orquera & Cabrera, 2020); (Tovar et al.2025).

To address these challenges, environmental sustainability indicators have been widely promoted as tools for monitoring ecosystem conditions, identifying critical pressures, and supporting decision-making processes. Indicator-based frameworks facilitate the integration of environmental, social, and economic dimensions, allowing for a comprehensive assessment of ecosystem sustainability (Becerra et al., 2013);(Rijalba, 2022). Among these frameworks, the Pressure–State–Response (PSR) model has been extensively applied due to its capacity to systematically link human activities with environmental conditions and management actions.

Despite the growing body of literature on sustainability indicators, most existing studies apply standardized or generalized indicator sets that are not sufficiently adapted to local socio-ecological contexts, particularly in high-altitude Andean lagoons (Maldonado & Moreno, 2023).. In Ecuador, previous research has largely focused on isolated environmental variables such as water quality, land degradation, or biodiversity loss, without integrating social perception, institutional capacity, and ecosystem

management into a unified assessment framework (Cárdenas et al.2019); (Vilchis et al.2023). Furthermore, the incorporation of local stakeholders' perceptions in the construction of sustainability indicators remains insufficiently systematized, despite their recognized importance for ensuring relevance, legitimacy, and long-term implementation, despite their importance for ensuring relevance, legitimacy, and long-term implementation.

This lack of context-specific, participatory indicator systems represents a critical gap in the assessment and management of fragile lagoon ECOSYSTEM. Without indicators tailored to local environmental dynamics and human pressures, management strategies remain fragmented and reactive, reducing their effectiveness in mitigating cumulative impacts from tourism, agriculture, and land-use change (Vizuete, 2025).

In response to this gap, the present study aims to develop a set of environmental sustainability indicators specifically adapted to the ecological, social, and institutional characteristics of the Yambo Lagoon, using a mixed-methods approach based on the Pressure–State–Response (PSR) model. By integrating quantitative data from surveys with qualitative insights from semi-structured interviews, this research seeks to identify key pressures, evaluate the current state of the ecosystem, and assess the effectiveness of existing management responses. The proposed indicator system is intended to support environmental planning, guide decision-making processes, and serve as a methodological reference for sustainability assessments in similar Andean and lacustrine ECOSYSTEM (Clavijo & Gutiérrez, 2023).

## Methods

### Study Design

This study adopted an exploratory mixed-methods research design with the objective of developing environmental sustainability indicators adapted to the specific ecological and socio-economic conditions of the Yambo Lagoon, located in the parish of Panzaleo, canton Salcedo, province of Cotopaxi, Ecuador (Figure 1).

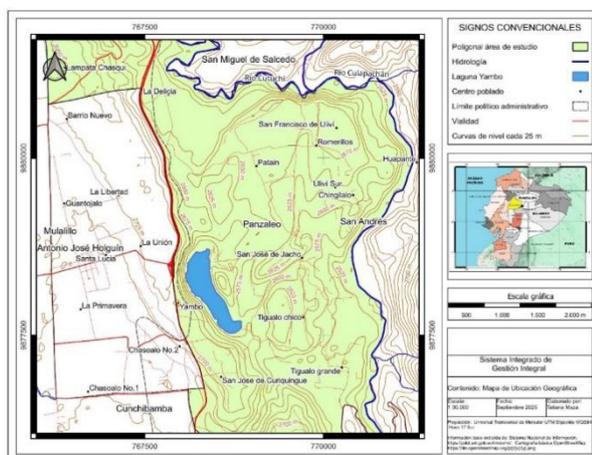


Figure 1. Location of the study area

The mixed-methods approach allowed for a comprehensive understanding of the perceptions of local stakeholders regarding ongoing anthropogenic activities and their effects on the lagoon ecosystem. This integration of quantitative and qualitative data facilitated the construction of context-specific sustainability indicators, ensuring their environmental relevance and social applicability (Tarupí, 2019). In addition, the approach enabled the integration of technical knowledge with local experiential knowledge, promoting community participation in ecosystem conservation and supporting the formulation of socially and environmentally viable management strategies.

During the research process, multiple data collection techniques were applied to ensure the acquisition of reliable and timely information. The quantitative component involved the use of structured questionnaires with Likert-scale items, administered to residents, visitors, and productive actors in the study area to assess perceptions of the current environmental condition of the Yambo Lagoon. The qualitative component consisted of semi-structured interviews, which were conducted to obtain in-depth insights into local environmental practices, institutional dynamics, and perceived ecosystem changes (Clavijo & Gutiérrez, 2023).

The case study method was employed, as it focuses on the detailed analysis of a clearly delimited territorial unit (Gómez, 2018). In this case, the Yambo Lagoon and its surrounding area constituted the unit of analysis. This method enabled a contextualized and systematic examination of the interactions between human activities and environmental conditions, considering ecological, social, and cultural factors that influence ecosystem management and sustainability.

### Sample selection

The study population consisted of three stakeholder groups associated with the Yambo Lagoon: (i) local residents, (ii) visitors/tourists, and (iii) productive actors (e.g., agricultural producers, vendors, and service providers operating in the surrounding area).

A non-probabilistic purposive sampling strategy was applied to capture diverse perspectives on environmental impacts and ecosystem use (González et al., 2019). A total of N = 346 participants were included in the study, comprising [X] residents, [Y] visitors, and [Z] productive actors.

The sample included participants of different genders and age groups (18 years and older), with residence status recorded to distinguish between local inhabitants and external visitors. The inclusion criteria were: (a) individuals aged 18 years or older; (b) direct interaction with or use of the Yambo Lagoon ecosystem; and (c) voluntary consent to participate in the study. Exclusion criteria included: (a) individuals with no knowledge of the study area; (b) minors; and (c) incomplete survey responses (Castillo, 2025).

All participants were informed about the objectives of the research, and verbal and/or written informed consent was

obtained prior to data collection. The study relied exclusively on voluntary participation and publicly acceptable ethical standards for social research, ensuring confidentiality and anonymity of respondents.

**Data Collection**

Data were collected through surveys and semi-structured interviews, after which descriptive and analytical procedures were conducted to identify the main environmental problems affecting the Yambo Lagoon ecosystem. This integrative approach enabled the analysis of both natural factors and anthropogenic activities influencing environmental quality, as well as the relationship between local practices and ecosystem degradation (Cevallos, Paredes, Calucho, & Toapanta, 2025).

Quantitative variables were measured using a five-point Likert scale (1 = very low impact to 5 = very high impact), capturing respondents’ perceptions of environmental conditions, resource use, pollution levels, institutional management, and conservation practices. Qualitative interview data were transcribed and thematically analyzed to complement and contextualize the quantitative findings.

Environmental, social, and institutional factors (Table 1) were identified based on an extensive review of prior studies on environmental sustainability in Andean and lacustrine ecosystems, including works by Bedon et al. (2018). This literature review provided the theoretical basis for the selection and operationalization of sustainability indicators, which were subsequently adapted to the current conditions of the Yambo Lagoon. The process also facilitated the identification of critical factors requiring prioritization for future monitoring and ecosystem management initiatives.

**Table 1**  
*Selection of factors for the study area*

**Prepared by: Authors (2025)**

Dimension	Variable	Factors
Environmental	Water quality	Turbidity level, degree of eutrophication, presence of contaminating or solid residues
	Soil use	Conflicts of use, level of erosion, extension of vegetation cover
Social	Human activities	The intensity of tourism, agricultural practices and livestock management

Institutional	Environmental management	The implementation of conservation measures, protection plans and the effectiveness of different environmental policies
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**Data analysis**

The analysis process was supported by the use of several primary and secondary sources, as well as data obtained in the field (Hernández et al. 2025). This information allows full characterization of the study area, considering aspects such as soil, vegetation, forestry suitability, soil use. The results obtained were used to identify the causes, effects and relationships between current human activities and the sustainability of the entire ecosystem.

Furthermore, it allowed us to establish an adequate integral reference framework for the process of developing indicators for environmental sustainability and the prioritization of the main problems, for the development and guidance of management and conservation strategies.

All information obtained was categorized and coded, seeking in this way the identification of different patterns and existing relationships, with reliable data, as well as representative data on the current natural problem of the ecosystem (Arias et al.(2015). For quantitative analysis, SPSS v.26 was used, which allowed the application of descriptive statistics (frequencies, percentages). In the case of qualitative elements, semi-structured interviews were analyzed through ATLAS.ti, for open coding, in an axial and selective manner, allowing for depth.

The Presión – Estado – Respuesta (PSR) model was implemented (Muñoz et al. 2025), which facilitates the identification and analysis in a systematic way of the entire structure of interactions between different human activities, the current environmental conditions of the ecosystem, as well as the actions implemented for their adequate management. Under this focus, three types of indicators are being developed: a) pressure, for the description of each direct or indirect influence that is caused by anthropic activities; b) status, which allows observing the current conditions of the ecosystem, thus evaluating its ecological integrity; c) response, which represents each of the measures, actions and policies that allow mitigating or correcting the environmental impacts caused. In this way, it facilitates the prioritization of critical areas and key environmental variables.

**RESULTS**

A high level of knowledge about the different elements of socio-environmental perception was evident (Table 2). 87% of participants recognize the lagoon's ecosystem, which favors their input and informed criteria in the development of indicators.

Large number of activities such as tourism, housing construction, health, employment are the elements that

represent the consumption of resources within the area, which suggests the great impact of anthropogenic activity. Likewise, 100% of the data obtained highlights the importance of environmental issues such as water use, land, biodiversity, which must be treated as a priority in addition to being included as indicators.

Accordingly, 100% of those surveyed consider that environmental management constitutes the basis that allows ensuring the natural development of the ecosystem, thus guaranteeing an adequate balance between the different tourist and ecosystem conservation activities. In the economic sphere, 92.77% manage to recognize the entire importance of an adequate articulation of the local

economy with each of the principles of sustainability for the territory, in an integral way. Finally, 99.13% of participants estimated that the analyzed variables were sufficient to carry out the diagnosis and development of each of the selected indicators.

**Table 2**  
*Results of the surveys conducted*  
**Source:** Authors (2025)

Question	Response option	Responses obtained	Percentage that represents
Did you know the Yambo Lagoon?	SI	301	87%
	NODE	45	13%
Do you believe that human activities (tourism, housing, education, employment, health, production and consumption) are a predominant factor in Yambo Lagoon?	SI	344	99.43%
	NODE	2	0.57%
Do you believe that environmental issues (water, air, land use, agriculture, biodiversity) are priorities for care in the Yambo Lagoon?	SI	346	100%
	NODE	0	0%
Do you believe that environmental management and ecosystem management are fundamental to the natural development of the Laguna?	SI	346	100%
	NODE	0	0%
Do you believe that an economic structure in the Yambo Lagoon helps to improve environmental dynamics?	SI	321	92.77%
	NODE	25	7.23%
Do you consider that the variables mentioned are sufficient to evaluate the sustainability of the Yambo Laguna?	SI	343	99.13%
	NODE	3	0.87%

Within the data analysis, 15 factors were determined for the development of indicators that were related to the following dimensions: a) human activity: agriculture, community, employment, education, economic structure, production and consumption patterns, housing, tourism, health (Table 3). b) environment: water, air, biodiversity, environmental management, ecosystem management, land use (Table 4).

The evaluation of the Agricultural Factor in the Yambo Lagoon area, according to Table 3, evidenced an

ecosystem dysfunction marked by high anthropic pressure, which negatively affects soil health and the entire water balance. The five key indicators demonstrated that the Use of Agrochemicals (Presión) was the dominant force of degradation, resulting in dependence on synthetic fertilizers, although productive in a short period, causing a critical decrease in the natural fertility of the soil by reducing organic matter and affecting the microbiota. In turn, response indicators such as the adoption of crop rotation and the use of organic allowances presented low to intermediate implementation levels, with impacts that

mitigation actions were insufficient to counter chemical and physical degradation of the substrate. This situation, combined with the scarce technology at risk and the poor management of the Management of Agricultural Plastic Waste (State), maintains an unsustainable cycle whereby the impoverishment of the soil intensifies the need for external inputs, alleviating the ecological functionality and the wide-ranging productive viability of the area.

In the evaluation of the Community Factor, for the study area, the socio-environmental pressure was evidenced in a moderate way derived from the integration of all indicators (Prison, State, Response). With pressure indicators, notable impacts can be observed without reaching critical levels. At the level of State indicators, they reflect low participation. Finally, in the Response indicators it is evident the set of community actions with efforts that do not achieve the elimination of existing pressures that are significant for the sustainability of the area. At the level of the State, community well-being and the participation of residents in conservation activities are at low levels, showing that current conditions are insufficient to guarantee the sustainability of the ecosystem with respect to Responsibilities, there is progress that is unfolding in an incipient manner for patterns and the promotion of different community activities and sustainable.

In relation to the Employment Factor (Table 3), the expansion of the tourist infrastructure represents the main pressure on the ecosystem, due to the construction of different buildings that cause changes in the natural balance. Pressure indicators, such as the increase in employment, with greater productivity and the creation of a greater number of jobs, suggest that tourism favors the entire process of economic development and simultaneously exerts pressure on different natural resources. State indicators are a reflection of the average impact caused and associated with the different environmental burdens that the ecosystem faces. Regarding the Respuesta, the application of different guidelines and policies for territorial planning in addition to the regulation of infrastructure are limited, highlighting a lack of different effective mechanisms that can compensate for each generated pressure, thus highlighting a need for the design of integral strategies that guarantee its conservation.

Regarding the Education Factor (Table 3), there is an insufficient delimitation on environmental knowledge, thus constituting an indirect pressure on the sustainability of the ecosystem. The Pressure Indicators, among them, the quantity and quality of environmental information that has been provided to visitors before, during and after the entire trip, with a scarce capacity of all technical personnel, shows a limited transition of each knowledge between the different actors that have been involved, thus being this lack that is affecting all integral understanding of the important ecological value of the ecosystem.

The State Indicators, showing the low level of awareness about the importance of sustainable practices, making it difficult for the community and visitors to perceive corrective measures. In terms of Respuesta, it is necessary to create entities that are responsible for the process of

environmental education combined with the implementation of a series of programs that adequately disseminate knowledge, thus avoiding a limited capacity on the part of the local community to be involved in each element of adequate environmental management.

As far as the Economic Structure Factor is concerned, when activities do not manage environmental premises, it generates a process of pressure on the sustainability of the ecosystem. Pressure indicators, such as the area's income index, as well as access to all economic information, reflect that the main activities are not considering adequate mechanisms for environmental compensation, increasing the exploitation of all resources. As far as the State is concerned, it is clear that the capacity of the entire community to maintain an economic balance with its surroundings is limited. The responses are centered on the creation of all economic information that allows and favors environmental retribution as part of mitigation strategies, integrating different environmental criteria into balanced economic planning.

The analysis of the Production Factor and consumption factors shows that the activities with a series of environmental harms exert a direct pressure on the lagoon, especially in the use and consumption of a series of products that are harmful to both health and the environment, generating solid waste in turn. State indicators reflect that there is a high volume of waste that is produced with inadequate disposal, thus increasing the contamination of the entire ecosystem, in addition to limited recycling and reuse practices. Respuesta actions, include the creation of different control and waste management systems, showing a low level of implementation, which is why corrective measures do not achieve a reduction of each negative impact, highlighting the importance and need to implement policies for effective waste management, promoting environmental sustainability in turn.

From the perspective of Factor Vivienda, every expansion of a change in use constitutes one of the main pressures on the ecosystem. Pressure indicators such as the surface of occupied or artificial soil reflect an increase in different settlements that degrade the environment. The State Indicators demonstrate that the settlement stability process can vary and that the increase in human activity is detrimental to the ecological carrying capacity of the area.

During the Respuesta, the measures that are implemented for the preservation of the surrounding area are limited, highlighting the need for more effective policies for an adequate process of territorial planning and soil management, thus protecting the ecosystem.

Regarding the Tourism Factor, the constant increase in visitors is exerting a great pressure on the lagoon, thus increasing the demand on different natural resources and all local infrastructure. Pressure indicators influence the rate of annual increases in visitors, territorial planning in addition to access to all information. State indicators demonstrate that there is a need for improved management and control systems over large numbers of visitors to guarantee the sustainability of natural areas. This is how Respuesta actions must implement plans for sustainable mobility and continuous assessments of environmental

impact, with the purpose of determining whether the different mitigation measures are effective, thereby strengthening planning and management of the entire flow of visitors.

The evaluation of the Health Factor shows that the entire organic structure for the health and well-being of the lagoon faces a variety of pressures that are indirect as a result of environmental contamination and insufficient management of natural resources. Pressure indicators, such as hygiene and community health regulations, reflect how contaminants that come from agricultural, tourist and residential activities are affected by the well-being of visitors and inhabitants. As far as the State is concerned, it was identified that with the implementation of plans and

projects for prevention and control of all contamination, it is limited, which shows a low level of resilience in the face of each health risk. Respuesta actions must be based on the elaboration of different control plans and hygiene regulations, which presents a framework for partial implementation, which shows that the integration of strategies is necessary for adequate environmental management accompanied by public health.

**Table 3**

*Assessment of factors: Pressure – State – Response (human activities dimension)*

Prepared by: Authors (2025)

Factor	Pressure	State (Specific indicators)	Answer	Main indicator
<b>Agriculture</b>	Agricultural expansion	- Use of different chemicals - Use of fertilizers - Total cultivable areas per inhabitant - Permanent area for each crop	Rotation practices along with roof care to avoid erosion	Agricultural education
<b>Community</b>	Socio-environmental development	- Socio-environmental acceptance among different visitors and residents Community well-being - The participation of residents in each activity	Patterns of development at community level compatible with the environment	Socioenvironmental acceptance
<b>Employment</b>	Expansion of tourist infrastructure	Employment Index Labor productivity - Work tasks that are acceptable	Efficient policies for sustainable infrastructure	Local employment index
<b>Education</b>	Limitation of environmental knowledge	- Type of environmental information that is provided - Training for each employee Literacy rate	Creation of different diffusing entities in the natural environment	Environmental information provided
<b>Economic Structure</b>	Economic activities without adequate environmental criteria	Local income index - Access to all information	Implementation of different environmental compensation indices	Revenue index
<b>Production and Consumption</b>	Use of harmful products and practices	- Use of harmful products Annual volume of waste - Recycling and the entire appropriate final disposal process	Different environmental management control and management systems	Use of harmful products
<b>Housing</b>	Expansion of the exchange of use of soil	Artificial soil - Stability of different settlements - Housing surface for each person	Protection measures for the entire natural environment	Artificial soil

Factor	Pressure	State (Specific indicators)	Answer	Main indicator
<b>Tourism</b>	Increase in visitors	<ul style="list-style-type: none"> <li>- Adequate territorial planning</li> <li>- Access to all information</li> <li>- Sustainable mobility</li> <li>- Assessment of each environmental impact</li> <li>- Visitor tax</li> </ul>	Sustainable tourism control systems	Territorial planning
<b>Health</b>	Pressures on all well-being and sanitary conditions	Community health <ul style="list-style-type: none"> <li>- Regulations for health and hygiene</li> </ul>	Prevention and control plans for contamination processes	Community health

In the Water Factor (Table 4), all pressure is concentrated on the use and exploitation of the water resource, mainly for each tourist, residential and agricultural activity. Pressure indicators include access to drinking water of great importance, as well as its control and use and organic contamination of the lagoon, which shows that the current management of the water resource is not optimal and contributes to environmental degradation. State indicators show that the entire water quality process, in addition to wastewater treatment, is deficient, which increases the risk of eutrophication and aquatic biodiversity. Regarding Respuesta actions, they must be oriented towards a sustainable, control and water treatment system, showing in turn intermediate levels for its implementation, which suggests the need for strengthening new water conservation strategies.

For the analysis of the Air Factor, the use of fossil fuels was evident on all tourist boats, constituting the main pressure on the ecosystem, with the generation of emissions that are contaminants and that affect the air quality. Pressure indicators, such as representing fuel consumption in addition to air pollution, thus showing that every process of recreational activity contributes significantly to the atmospheric contamination of the area. While at the State level, it was identified that there are not enough controls or constant monitoring of emissions, thus maintaining the environmental risk. Respuesta actions must be oriented towards the creation of policies and guidelines for the control of the entire contamination process, thus promoting alternatives that are sustainable for the ecosystem.

The Biodiversity Factor reveals that the entire economic process and development is linked to tourism, agriculture and the generation of pressure on the lagoon, affecting in great proportion the diversity of species and protected habitats. The pressure indicators show in this way an expansion of different human activities altering the ecosystem and conservation areas. Regarding State indicators, reflect that current policies for the protection of species in addition to the surface where they live are insufficient to be able to guarantee the ecological resilience of the area. Respuesta actions, such as the management and management of natural resources as well as the protection of the entire ecosystem, must be

implemented immediately accompanied by different conservation policies.

In the Environmental Management Factor, a series of undesired impacts are generated that are derived from construction processes that are tourist attractions and with the generation of waste representing the main pressure on the lagoon. Pressure indicators include a number of controls carried out, with the incorporation of environmental criteria and waste management policy, thus reflecting current practices that are not sufficient to prevent environmental degradation. State indicators show the entire implementation of different measures for prevention and control are partial, with a series of deficiencies in the protection of species and ECOSYSTEM. Respuesta actions, such as the process of elaborating environmental management plans and the supervision of tourist activities, present low levels of execution, indicating that it is essential to strengthen all environmental management, minimizing impacts and ensuring all sustainability of the ecosystem.

When analyzing the data related to the Ecosystem Management factor, we observed how each of the benefits and services that are provided by the lagoon are used and approved. Pressure indicators, such as the control of natural and anthropic risks, in addition to the low-pressure ecosystem, reflect poorly planned resource exploitation. As far as the State is concerned, it was possible to identify that each conservation practice is insufficient and vulnerable in the face of different natural and human risks. Respuesta actions must be centered on the restoration of the ecosystem and the definition of ecological limits, with the integration of management programs that ensure the functionality of the lagoon over a wide range.

Finally, the Factor Utilization of the Tierra, showed that the different activities for the cultivation processes in addition to the expansion of human settlements are direct pressures on the sustainability of the ecosystem. Pressure indicators include every surface element affected by erosion processes given the different formal and informal settlements along with the load capacity of the area. State indicators reflect signs of degradation along with the loss of vegetation cover with an increasing deterioration of the ecological support capacity. The Respuesta actions are focused on the management and use of land with territorial

planning, seeking to maintain a balance in human activities and the preservation of the ecosystem.

*Assessment of factors: Pressure – State – Response (environmental dimension)*

**Table 4**

Prepared by: Authors (2025)

<b>Factor</b>	<b>Pressure</b>	<b>State (Specific indicators)</b>	<b>Answer</b>	<b>Main indicator</b>
<b>Water</b>	Use and exploitation of water resources at intensive levels	<ul style="list-style-type: none"> <li>- Organic contamination of the entire ecosystem</li> <li>- Access to clean water to achieve adequate human consumption</li> </ul>	<ul style="list-style-type: none"> <li>- Control and efficient use of drinking water</li> <li>- Treatment of different waste waters</li> <li>- Supply systems, their use and all their use under sustainability criteria</li> </ul>	Water quality
<b>Air</b>	Use of fossil fuels on different vessels	<ul style="list-style-type: none"> <li>- Daily consumption of fossil fuels</li> </ul>	<ul style="list-style-type: none"> <li>- Management and control of air contamination</li> <li>- Creation of different systems or emission control policies</li> </ul>	Air quality
<b>Biodiversity</b>	Socio-economic development without adequate planning	<ul style="list-style-type: none"> <li>- Abundance of all species</li> <li>- Percentage of the entire protected surface in relation to the total</li> </ul>	<ul style="list-style-type: none"> <li>- Sustainable management and management of natural resources - Implementation of different areas of ecosystem development</li> </ul>	Abundance of species
<b>Environmental Management</b>	Impacts on the desired results from the construction of different tourist attractions	<ul style="list-style-type: none"> <li>- Incorporation of different environmental criteria into projects</li> <li>- Number of all environmental controls carried out</li> </ul>	<ul style="list-style-type: none"> <li>- Policies for waste management - Preventative controls (illegal disposal, waste, disposal)</li> </ul>	Environmental controls achieved
<b>Ecosystem Management</b>	Use and benefit of each ecosystem good and service	<ul style="list-style-type: none"> <li>- Percentage of sweat in each of the appropriate conditions</li> <li>- Control of natural and anthropogenic risks</li> </ul>	<ul style="list-style-type: none"> <li>- Low protection ECOSYSTEM</li> <li>- Practices for preserving and establishing ecological limits</li> </ul>	ECOSYSTEM under protection
<b>Land Use</b>	Agricultural activities, in addition to crops around the lagoon	<ul style="list-style-type: none"> <li>- Surface affected by erosion</li> <li>- Formal and informal human settlements</li> </ul>	<ul style="list-style-type: none"> <li>- Management of the use of land and natural landscape</li> <li>- Application of each load capacity criteria</li> </ul>	Surface affected by erosion

The results of the interviews carried out (Figure 2) with the different actors and visitors to the lagoon revealed their perception of the entire environmental state and the ecosystem management processes. It became clear that the lagoon is recognized as an ecosystem of high tourist influence, which is valued for all its natural attraction, accessibility and all the diversity of each recreational activity it offers. However, the interviewees realized that

the entire lagoon management process is limited, highlighting the need for a formal sustainability structure that regulates each activity and its conservation.

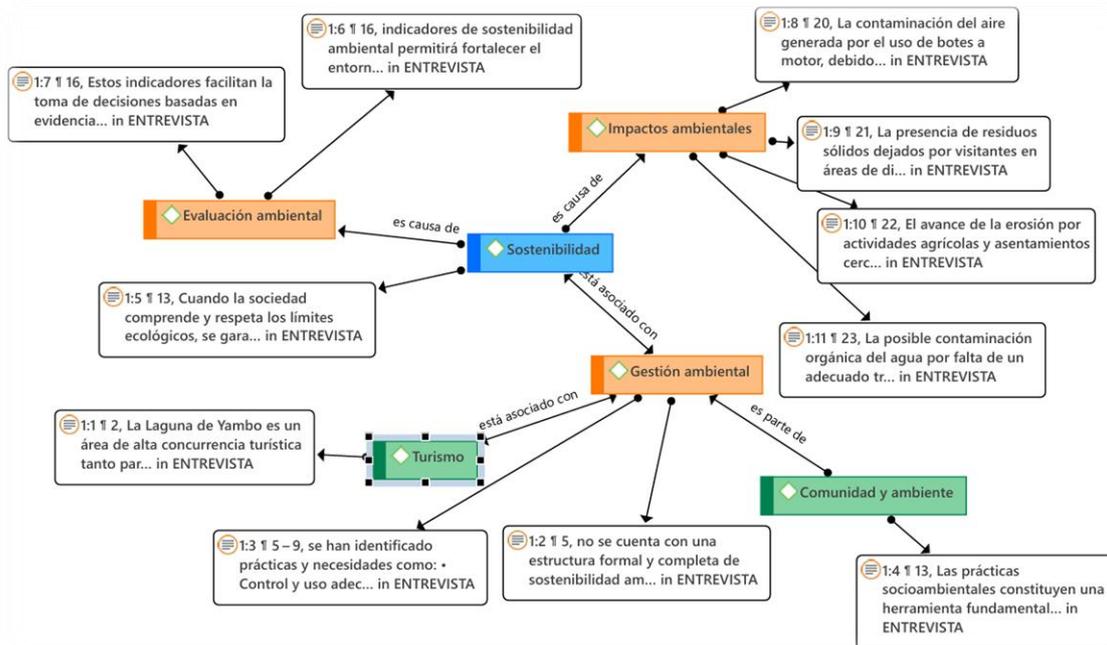
Asismism, they identified existing environmental practices, such as water control, rudimentary waste management, air contamination, partial conservation of the entire ecosystem and restrictions that are considered

insufficient for the proportion of negative activities that are generated

Outline of the interview analysis

Source: Authors (2025)

Figure 2



## DISCUSSION

The results validate the existing perception at a socio-environmental level and in a significant way regarding the importance in the development of the different indicators. The importance of your understanding is clear evidence about the current knowledge that exists about the ecosystem, which coincides with the investigations carried out by Mendoza et al. (2022), which emphasize the importance of community interaction and participation to guarantee the conservation of these ECOSYSTEM. This convergence of results suggests that all selected indicators can be sustained with a broad social base.

Likewise, this unanimous perception of the importance of each environmental resource, such as soil, air, water, biodiversity, reflects that for the development of indicators it is important to focus on the conservation of resources, guaranteeing the resilience of the ecosystem. For authors like Sánchez et al.(2025), which focuses on the fact that trophic conditions, especially those linked to phosphorus, demand an environmental management process that is a priority to consider in eutrophication processes, equally supporting the need for criteria integration.

There is an aligned vision about the importance of the economic structure that coincides with what was expressed by Zahira et al. (2025), they state that economic growth without appropriate criteria can increase ecological pressures and the degradation of an area. Emphasizing that every tourist activity can only be maintained if it is articulated with a series of public policies and economic strategies that favor the

preservation of the entire ecosystem. However, the present investigation adds a differential contribution in which the group of respondents recognizes the need to articulate all tourist activity with different public policies that guarantee all its preservation, demonstrating in this way the integrative vision between the economy, conservation and governance, providing a systemic approach that is expressed from the city to an appropriate extent. planning within the ecosystem.

The importance of the indicators being developed depending on the situations of each area was observed. In the same way, Vidal(2021), focuses on the modernization of environmental management with the support of technical instruments that favor the monitoring and analysis of each institutional decision. It is through this type of investigation where there is no technical limitation where it is possible to incorporate the entire perception of the community, seeking in this way an anticipation of different risks and all guidance in an appropriate and effective manner where institutional decisions must be carefully selected.

The findings obtained in surveys and interviews are evidence of the importance that the ecosystem represents for the population. For Guarín & Vitoncó (2022) this stance is consistent with the elements planted, emphasizing the importance of measurement and evaluation of each resource for its implementation in different effective policies.

Asimismo, Garcia (2025), highlights that all environmental governance is the fundamental basis for the development and implementation of elements with technical and scientific levels that must be articulated across the entire social sector. This greater level of

maturity within the environmental part allows the strengthening of indicators seeking así the incorporation of a solid social base supported by evidence of the entire functional understanding of the ecosystem, which allows the articulation of economic, ecological and governance dimensions, in addition to socially validating all its relevance.

The results obtained from Cartuche and Noriega(2018), which emphasizes that socio-environmental perception is one of the key elements for all ecotourism development that is sustainable in ECOSYSTEM. For this, it is essential that there is a unanimous assessment of environmental management as a basis for any process of ecological balance, community integration and recognition of each ecological limitation that are fundamental for adequate management of the entire territory, thereby confirming the current environmental perception.

At the environmental and productive level, elements within the agricultural factor are aligned with the characteristics planted by De la Ossa et al.(2024), highlighting the importance of production systems with a conventional approach generates a greater proportion of soil degradation levels without the incorporation of soil protection and sustainability practices due to the lack of rotation in crops, and the use of a large amount of organic allowances, thus increasing the ecological vulnerability of soil.

## CONCLUSIONS

The work carried out in an integral way highlights the imbalance in the interaction that exists between human activities and the entire natural environment, where the main environmental pressure activities are led by the set of agricultural practices and tourist activities, which in turn is reflected as a high and even significant environmental awareness, which more than 99% of those surveyed recognize this series of impacts, providing a level with a solid foundation so that sustainable management of the ecosystem can develop.

From the environmental dimension, the different water resources, air and biodiversity present major symptoms of deterioration, it is important to recognize the indicators to be able to observe the ecological support capacity of the lagoon. With social perception being 99.13%, they consider that each of the selected variables is appropriate for the assessment of sustainability, which in turn supports

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control measures, as well as environmental improvements.

The indicators show associations with different human and environmental activities with high levels of anthropogenic pressure in addition to limited institutional and community response. The indicators reveal that they must be considered as the main drivers of pressure on agriculture, tourism, the process of expansion of homes and intensive use of soil, water and biodiversity. These elements are generating a process of progressive degradation in a particular and visible way throughout the loss of soil fertility, the increase in solid waste and all water contamination, erosion, the atmosphere and the reduction of natural habitats.

## Implications

The proposed sustainability indicators provide a practical framework for understanding how tourism, agriculture, and land-use change interact to affect the ecological integrity of the Yambo Lagoon. By integrating social perception with environmental assessment through the PSR model, the study highlights the importance of participatory approaches in ecosystem management. The findings imply that without context-specific indicators, management actions remain fragmented and reactive. The indicator system developed can support evidence-based decision-making, improve environmental governance, and facilitate periodic monitoring. Moreover, the approach offers methodological relevance for similar high-altitude lagoon ECOSYSTEM facing cumulative anthropogenic pressures in the Andean region and other comparable socio-ecological contexts.

## RECOMMENDATIONS

It is recommended that local authorities and environmental managers adopt the proposed indicator system as a formal monitoring tool within territorial and environmental planning processes. Priority actions should focus on regulating tourism intensity, promoting sustainable agricultural practices, and strengthening wastewater and solid waste management. Environmental education programs targeting residents and visitors should be reinforced to enhance community participation and compliance. Institutional coordination must be improved to ensure effective implementation of response measures. Future research should validate and refine the indicators through longitudinal monitoring and integrate quantitative environmental measurements to strengthen their predictive and management value..

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