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CHALLENGES OF PARTICIPATORY MONITORING FOR WATER MANAGEMENT

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Abstract

The article focuses on the analysis of various methodologies and challenges of participatory monitoring for the management of water heritage at the global level, as well as the application of a method in a region of Colombia. The Prisma methodology was used for the analysis of the information using different databases, processed with the Vosviewer and Bibliometrix software. The analytical hierarchy methodology (AHM) was applied with the qualification of experts to prioritize indicators. This involved the establishment of comparisons, calculation of priority values, consistency analysis, aggregation of values and decision-making. The study identified 244 indicators used in participatory processes. These were categorized into management, landscape, hydrological, socio-cultural, biological and physicochemical. Finally, a pilot test was carried out in 6 peasant communities, highlighting the diversity of socio-ecological contexts in the monitoring points. This showed that approaches adapted to each situation are required. The main challenges in monitoring were of a technical nature, such as the need to maintain data coherence, permanent monitoring and adjustment of indicators and of an administrative nature related to the empowerment of communities for the sustainability of monitoring projects.

***Keywords**: Participatory monitoring; Indicator; Moor; Paramo; Hierarchical analytical process; Wetland; water management*

Introduction

Paramo ecosystems and water sources play a crucial role, especially in the regulation of the water cycle. They are fundamental in preventing floods, landslides and avalanches, in addition to their contribution to soil regulation [1]. Given the growing influence of climate change at the global level, it is imperative to provide special protection to these ecosystems [2] since it has influenced the loss of their biodiversity [3]. Its regulatory function is not only vital for the preservation of the natural environment but also contributes significantly to mitigating

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the adverse impacts of climate variations on society and the economy [4]. The need to protect these environments becomes even more pressing in the face of the increasing effects of climate change, underlining the strategic importance of conserving and sustainably managing these ecosystems [5].

The ways in which water sources contribute to human well-being are diverse and far-reaching. These ecosystems retain a unique biodiversity, highlighted by a high level of endemism in animal and plant species, both in terrestrial and aquatic environments. In addition to serving as a refuge and breeding ground for numerous species in a conservation situation. On the other hand, they play a crucial role in economic development for the regions [6]. Water, a vital resource, where, in short, the entire shaping character of society has been concentrated [7].

Its significant fragility is related both to natural causes, changes in rainfall patterns [8] and to human causes, derived from practices related to drainage, excessive grazing,and alterations in the water regime [9]. The accelerated loss of many wetlands is attributed, in part, to ignorance of their dynamics and ecology. In addition, excessive consumption of natural resources has caused widespread environmental deterioration, contributing to a global environmental crisis [10].

Despite the fact that through Colombia's national system of protected areas, important ecosystems have been conserved, only 3.9% of wetlands are under some form of protection. The rest are managed unsustainably and their biological or hydrological potential is unknown. As citizen awareness of wetland functions and values increases, the general trend is far from presenting a stabilization of ecosystems [11]. On the contrary, the inevitable reduction of these ecosystems can be foreseen in the immediate future.

In recent decades, an increase in the loss of ecosystems due to anthropogenic activities has been observed, including urbanization and industrialization [12], which underlines the need to implement both monitoring and management measures. Water is important for life and development in general [13]. This becomes essential to ensure the balance and sustainability of natural resources, given the growing constraints on supply capacity to meet the ambitious demands of the market and diverse lifestyles. The participation of communities becomes crucial for the management of water heritage. All actors must be integrated to ensure sustainability [14].

Monitoring is not only limited to answering questions related to water heritage management but also fosters a culture of inquiry, questioning and reflection. Participatory monitoring, in particular, plays a crucial role by actively engaging local communities, experts and other stakeholders in data collection and analysis [15].

In addition to being a valuable source of information, monitoring aspires to be a catalyst for learning processes, both individually and collectively [16]. By encouraging active participation in data collection and analysis, a sense of ownership and responsibility toward water heritage is fostered, thus strengthening informed and sustainable decision-making.

In the context of water heritage management, participatory monitoring also plays a crucial role in compliance with important regulations [17]. For example, it contributes to ensuring equitable access to ecosystems, monitoring their proper use, promoting the conservation of biodiversity and ensuring the fair distribution of the benefits generated.

This article presents the methodological process undertaken for constructing a battery of 244 indicators, prioritized through the Analytical Hierarchy Method (AHH), followed by its application in a pilot test involving six communities, some located in the Paramo area of the Chinchiná river basin in the central region of Colombia.

Experimental

The research conducted is framed within descriptive-qualitative research, as its focus is systematically describing the characteristics and relationships of the population with its surrounding ecosystem.

The population for the application of the pilot test of the monitoring methodology corresponded to the Chinchiná River basin in the central area of Colombia. Six communities were included in the study, involving participants of all ages, including children, youth and adults.

Method

For the methodology, three main phases were determined:

- ✓ *Phase 1. Evaluation of Various Methodologies for Participatory Monitoring of Wetlands*

Initially, a battery of indicators was constructed by drawing upon various experiences in participatory monitoring of wetlands, both within Colombia and internationally. Information was collected from existing studies conducted in the study area, as well as from relevant literature.

The analysis of the information was conducted using the PRISMA methodology, which primarily involved four phases: defining the research question, establishing inclusion and exclusion criteria, conducting database searches, selecting articles and extracting information. The guiding question for the information search was as follows: What methodologies have been utilized in participatory monitoring and what indicators have been employed for such monitoring in water sources? For the information search, four search queries were constructed, which were analyzed using the Scopus database and Web of Science. The data were processed using VOSviewer and Bibliometrix software to obtain the most accurate information regarding the primary publications related to the study objective. Additionally, the search was conducted on Google Scholar and direct interviews were conducted with institutions that have experience working with indicators for wetland monitoring. The aspects related to participatory monitoring in watersheds were analyzed, including methodologies, approaches and strategies for systematizing data.

For the development of this study, both management indicators and monitoring indicators were considered. The former are aimed at analyzing the impact of processes implemented in water sources, such as ecosystem restoration, implementation of payment strategies for environmental services, delineation of yellow lines, among others. On the other hand, surveillance indicators are oriented towards assessing the state of water sources, including supply conditions, impact of productive systems on sources, among others, which are further described in the classification of the indicators.

Faced with databases such as Scopus and Web of Science, we opted to address the following search equations (Table 1).

Table 1. Boolean searching equations

Equation	Results
((monitoring, AND indicators AND wetlands) AND (control AND management)) (participatory AND monitoring)) AND (wetlands)	186
(TITLE-ABS-KEY (participatory AND monitoring)) AND (water)	1129
participatory AND water AND monitoring AND with AND COMMUNITIES	256
(participatory AND monitoring AND water)	538

We opted to work with the second equation and then apply the criteria for inclusion and exclusion of citations.

✓ *Phase 2. Determination and Prioritization of Sustainability Indicators for Monitoring Purposes*

Based on the constructed battery, a classification was created for management indicators related to restoration processes, conservation measures, policy implementation, payments for environmental services, among others and monitoring indicators related to changes in water levels, biodiversity shifts, physicochemical parameters, among others, as described below. Following this general classification, a further subclassification was conducted, resulting in 9 management and monitoring indicators, each with their respective sub-indicators.

Application of the AHP Methodology for Ranking the Indicators

For the ranking of the indicators, the Analytical Hierarchy Process (AHP) methodology was utilized, as proposed by Thomas L. Saaty [18] in 2008, as described by Lamis Rivero et al. [19]. In this method, experts assess the relative importance of different indicators through paired comparisons. According to Thomas L. Saaty [18], the AHP method is based on three fundamental principles: the construction of hierarchies, establishment of priorities and logical consistency. For the case study, a pairwise comparison matrix was constructed to assess the relative importance between two criteria, facilitating prioritization between the variables. Comparisons are always made from the row to the column, giving precedence to the row and assigning a whole number to it.

Selection and Qualification of Experts

The selection of experts was conducted for each group of indicators. For each group and subgroup of indicators. The task was carried out with an approximate number of 6 to 8 different experts, resulting in a total of 70 experts.

The comparison matrix was created for each of the indicators, utilizing the Tomás Saaty [18] scale, with adaptations made for its implementation (Table 2).

Table 2. Indicator comparison matrix. Adapted from Saaty [18]

Numerical Scale	Reverse	Verbal Score	Explanation
1	1	Equally Significant	Two indicators contribute equally
3	1/3	Moderately important	Slight preference for one indicator over another.
5	1/5	Strongly important	Slight preference for one indicator over another.
7	1/7	Very strong or demonstrated significance.	Much more preference of one indicator over another. Demonstrated preference
9	1/9	Extremely strong importance	Clear and absolute preference for one indicator over another
2,4,6,8			Intermediate between previous values

For comparing each criterion, the question was posed: To what extent does this element (or activity) surpass the element with which it is being compared in terms of ownership, contribution, dominance, influence, satisfaction, or benefit? Achieving the Grade According to the Numerical Scale.

Through the panel of experts, the importance of the criteria to be considered was determined on a scale of 0 to 100%. Subsequently, each indicator was rated within its respective group or category on a scale of 1 to 9, where 1 represents the lowest importance and 9 the highest.

Next, each indicator was weighted according to its assigned percentage of importance. Subsequently, the results of each indicator within each weighted criterion were aggregated. This process determined the significance of each indicator within its respective group. Finally, the graphical quadrant analysis was conducted to determine the overall importance of each indicator within the quality analysis.

After the experts provided their ratings, the inverses were applied. This means that if one criterion was given greater weight over another in the column, its inverse would be considered in the row. Subsequently, the scores assigned to each indicator were totaled, followed by the normalization of the assigned weights. This involved dividing each weight by the total weight. Finally, the average score for each indicator was calculated.

Consistency Index

Once all the averages were calculated, the consistency ratio was derived. This ratio was multiplied by the weighting and subsequently, the consistency index was determined using the following formula: $Cl = (nmax - n)/(n-1)$. Random consistency was then calculated using the following formula: $RI = [1.98 - n(n-2)]/n$. Finally, the consistency ratio was calculated using the following formula: $CR = CI/RI$.

Afterward, a final assessment was conducted using the indicators that received higher weights, employing evaluation criteria described below, as per the adaptation of the Indicator Guide methodology [20]:

Clarity for the Community: This criterion evaluates the clarity of the indicator, assessing whether the technical concept is sufficiently understandable for both professionals and the rural community, thereby minimizing ambiguity.

Relevance to the Community: This criterion assesses the indicator's relevance to the community's needs and objectives. It focuses on whether the indicator effectively measures wetland deterioration and is pertinent for management purposes.

Community Monitorability: This criterion evaluates whether the indicator can be easily monitored by the community from a technical perspective. It assesses whether the indicator is straightforward to calculate and replicate.

Economic Benefit for Institutions and the Community: This criterion compares the benefit of obtaining the necessary information for the indicator against the economic or human cost involved. If the benefit outweighs the cost, the indicator is considered economical.

- ✓ *Phase 3. Application of the Pilot Test of Participatory Monitoring of Surveillance and Management on the Prioritized Indicators.*

The objective of this phase was to validate, adapt, improve and refine certain aspects of the monitoring proposal. Additionally, this phase facilitated the socialization and ownership of the project within the community, as well as the management of the tools required for monitoring each sub-indicator. For this pilot test, the following methodology was employed:

Location of Data Collection Areas

With the assistance of a pre-prepared map, strategic areas were identified for conducting monitoring activities and identifying the families residing there, potentially involved in the project. Additionally, ABACOS (Rural and Urban Aqueduct Supply Areas) were identified. Routes for field trips with the community were identified and marked accordingly. Prior visits were conducted by the team to identify areas of interest and gain clarity on transportation options, access to farms, provision of food, safety considerations, weather conditions, river levels and necessary materials required for fieldwork, among other factors.

Preliminary Workshop

A preliminary workshop was conducted to explain the monitoring objectives and the community's intended participation. Kits were provided to allow participants to familiarize themselves with the tools. A questionnaire was administered to identify any previous similar projects, the community's existing knowledge, past monitoring parameters and ongoing involvement in related initiatives.

Team and Job Roles

For the monitoring process, a diverse range of participants, both internal and external to the community, were involved. Given the technical nature of the project, it was essential to have trained personnel who could not only handle the technical tools but also prepare community members for their use. Guidelines proposed by *A. Yepes et al*. [21] outline various roles such as a community technical head, community supervisors, community technical assistants, administrative assistants and community representatives.

Once the roles of the participants were established, a schedule of field trips was prepared for each group involved in the monitoring process.

Information Gathering

With the prioritized and selected indicators, the necessary measurement instruments were procured. Similarly, guidelines and protocols for the use and monitoring of each indicator were formulated. The search was filtered to prioritize instruments that were user-friendly, capable of measuring multiple parameters, cost-effective and provided valuable information for the project.

Results and Discussions

The process of searching, classifying and organizing participatory monitoring information took place in various settings. The studies were systematized using Vosviewer, followed by an analysis to identify the most representative institutions, authors and keywords associated with participatory monitoring.

The analysis yielded a total of 204 co-occurring keywords across 7 thesauri. After filtering for groups with a minimum of 2 keywords, there were 21 distinct concepts closely related to participatory monitoring. The following graph (Fig. 1) illustrates the concepts most strongly associated with participatory monitoring.

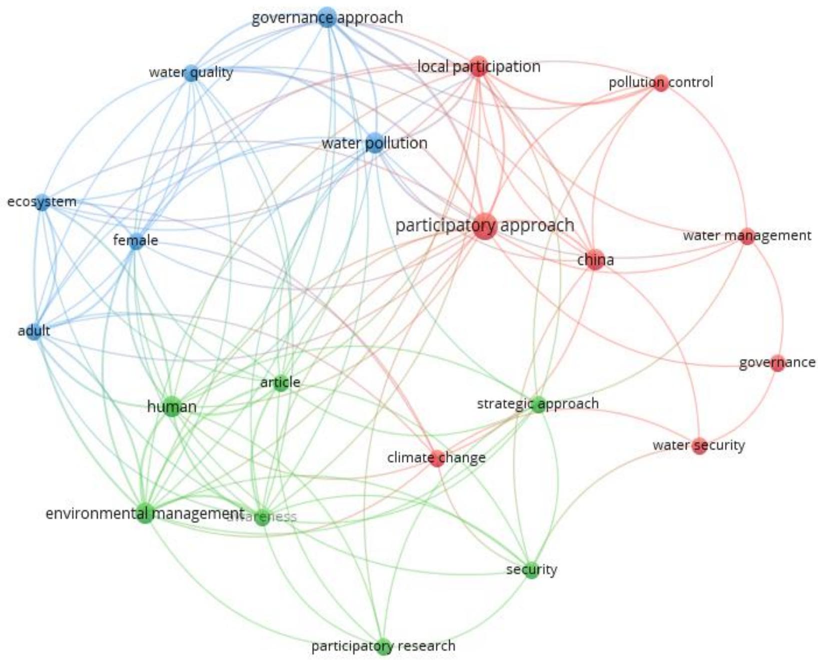

Fig. 1. Key concepts and themes surrounding participatory monitoring

After reviewing articles on Google Scholar that were not indexed in Scopus or Web of Science, a matrix was created to facilitate the inclusion and exclusion process. From these articles, environmental indicators were extracted, resulting in a total of 244 indicators studied by various communities in a participatory manner. These indicators were then classified and subcategorized, as illustrated in the table 3.

Table 3. Indicator Battery Rating

General Indicator	Level 1 Indicators	Level 2 Indicators
Management Indicators	Number of families that have adopted good management practices. Number of people participating in the different activities that involve restoration. Restoration success. State of protective fences. Conservation and restoration agreements - payment for environmental services	Management indicators had no level 2 indicators
Surveillance Indicators	Landscape Indicators	Fragmentation, buffer zone, vegetation cover, impacts of deforestation
	Hydrological indicators	Decrease in water flow in the wetland Internal flow Evapotranspiration Time series of flow rates, Presence/ Absence of water mirror, Increase / decrease in water level, Presence/Absence of water tributaries (water inlet), Presence/Absence of water effluents (water outlet)
	Biotic and biological indicators	Presence or absence of animal species, Presence of predatory species of wild flora and fauna, Presence/ Absence of species of aquatic and semi-aquatic flora typical of the wetland, Presence/ Absence of species of own terrestrial flora Presence or absence of clearings. Height and degree of coverage of plants according to their biological type. Phenology (presence/absence of leaves, fruits, or flowers). Presence or absence of macroinvertebrates. Presence of invasive species. Percentage of coverage of introduced species. Loss of native biodiversity. Population size. Presence/absence of rare, endemic, protected, threatened species. Extent of water mirrors. Presence of habitat burns.
	Physical-Chemical Indicators of Water	Temperature Ph Conductivity Suspended Solids Nitrates Dissolved Oxygen Phosphates COD Turbidity
	Socio-economic indicators	Existence of traditional knowledge and practices of use. Presence/Absence of contamination by spills. Presence/Absence of sources of disposal of garbage and debris. Presence/Absence of invasion of water round. Presence/Absence of semi-movents and/or grazing of semi-movents. Presence/Absence of adequate perimeter enclosure. Presence/Absence of organizations or social groups linked to wetland conservation. Number of Educational Institutions whose PRAES include the development of activities related to the wetland. Presence or absence of disease-transmitting vectors. Food security. Monthly catch of fish. Species used for firewood. Extension of the agricultural and livestock frontier

As depicted in the table above, numerous indicators persist even after the initial classification. Therefore, it was imperative to proceed with the ranking of the indicators to facilitate decision-making. This process is elucidated below:

Application of the AHP Methodology for Ranking the Indicators

Construction of Indicator Matrix:

The following matrix illustrates one of the monitoring indicators (physicochemical) in which the AHP methodology was applied, evaluated by a consensus of experts. In this particular case, 7 experts participated in the assessment. According to Table 4, temperature, pH, conductivity, suspended solids and turbidity contribute equally to the monitoring process. However, there is a significantly greater preference for nitrates, dissolved oxygen, phosphates and chemical oxygen demand (COD).

Table 4. Expert Rating Table for Physicochemical Indicators

Indicators	**Temperature**	**pH**	**Conductivity**	**Suspended Solids**	**Nitrates**	**Dissolved Oxygen**	**Phosphates**	**COD**	**Turbidity**
Temperature	1.0	1.0	5.0	5.0	0.2	1.0	0.2	0.2	1.0
Ph	1.0	1.0	5.0	5.0	0.2	5.0	0.3	0.2	1.0
Conductivity	0.2	0.2	1.0	1.0	0.2	0.2	0.2	0.2	1.0
Suspended Solids	0.2	0.2	1.0	1.0	0.2	0.2	0.2	0.2	1.0
Nitrates	5.0	5.0	5.0	5.0	1.0	1.0	1.0	1.0	5.0
Dissolved Oxygen	1.0	0.2	5.0	5.0	1.0	1.0	1.0	1.0	5.0
Phosphates	5.0	3.0	5.0	5.0	1.0	1.0	1.0	1.0	5.0
COD	5.0	5.0	5.0	5.0	1.0	1.0	1.0	1.0	5.0
Turbidity	1.0	1.0	1.0	1.0	0.2	0.2	0.2	0.2	1.0
TOTAL	19.4	16.6	33.0	33.0	5.0	10.6	5.1	5.0	25.0

Own source based on expert rating

After the experts' assessment and the application of the matrix in the consensus process, weighting was performed and the consistency index was determined for each weighted indicator. In the case presented below, the following results were obtained, in table 5. In table 6 is presented the consistency index.

Table 5. Normalized Matrix

Normalized Matrix			**Weighing**						
0.052	0.060	0.152	0.152	0.040	0.094	0.039	0.040	0.040	0.074
0.052	0.060	0.152	0.152	0.040	0.472	0.065	0.040	0.040	0.119
0.010	0.012	0.030	0.030	0.040	0.019	0.039	0.040	0.040	0.029
0.010	0.012	0.030	0.030	0.040	0.019	0.039	0.040	0.040	0.029
0.258	0.301	0.152	0.152	0.200	0.094	0.195	0.200	0.200	0.195
0.052	0.012	0.152	0.152	0.200	0.094	0.195	0.200	0.200	0.140
0.258	0.181	0.152	0.152	0.200	0.094	0.195	0.200	0.200	0.181
0.258	0.301	0.152	0.152	0.200	0.094	0.195	0.200	0.200	0.195
0.052	0.060	0.030	0.030	0.040	0.019	0.039	0.040	0.040	0.039

Table 6. Consistency Index

Consistency Index	**Value**
$CI = (n_{max} - n)/(n-1)$	0.207
$RI = 1.98\,(n-2)/(n)$	2.200
$CR = CI/RI$ $CR < 0.1\ Consistent$	0.094

As described in the methodological process for each of the first and second-level indicators, the same qualification process was conducted as demonstrated with the physical-chemical parameters.

Expert Discussion:

Below are the expert inputs for rating the indicators:

- *Biotic and biological indicators:*

Considering the extension of the matrix, experts proposed consolidating certain indicators to enhance completeness. Specifically, indicators related to the *presence/absence of birds, fish, amphibians, mammals and reptiles* were integrated into a single indicator called *"Presence or Absence of Animal Species"*. Similarly, the indicators related to the "*presence/absence of predatory species of wild flora and fauna"* were initially separated but were consolidated into a single indicator for simplicity and clarity. The significance of the indicator "loss of native biodiversity" was underscored due to its ability to provide insights into the state of the ecosystem, indicating its conservation status or potential deterioration. Furthermore, the population size was acknowledged as another crucial indicator offering valuable information. However, it was noted that in certain instances, a high population size may not necessarily indicate a healthy ecosystem, especially if the population comprises non-native species that proliferate and threaten native biodiversity.

Landscape Indicator:

The experts' insights and suggestions were carefully considered for refining the classification of indicators. The experts reached a consensus during the rating process, assigning values to each indicator based on their perceived relevance according to the numerical scale.

Cultural and socioeconomic indicators:

In the qualification process, experts suggested merging two criteria, as they believed the themes were correlated. The indicators *"presence or absence of disease-transmitting mosquitoes"* and *"presence or absence of pests (rats)"* were unified, resulting in the final indicator of *"presence or absence of disease-transmitting vectors"*. Considering that the indicator for pests (rats) also signifies an increase in anthropic presence in the area and particularly in the nd area, the presence of mosquitoes tends to decrease.

In the assessment of the indicators *"Existence of traditional knowledge and practices of use" and "Presence/Absence of semi-movents and/or grazing of semi-movents"*, it is acknowledged that traditional practices have impacted land use, altering the natural hydrology of ecosystems over time.

The *"monthly fishing catch"* indicator highlights that the area of interest does not witness a significant percentage of fishing for food; instead, recreational or sport fishing is prevalent. Consequently, this factor contributes to a lower rating on the numerical scale.

In the *"species used for firewood"* indicator, it's noted that presently, the felling of firewood is prohibited and closely monitored in the area. Firewood is sourced, marketed and transported from elsewhere.

In the case of the *"presence or absence of garbage and debris disposal sources"* indicator, several related indicators are identified, suggesting a direct correlation between them. It is noted that there is no selective waste collection route in the area. Consequently, waste is either buried, burned, or disposed of in rivers and streams, ultimately affecting the *"presence or absence of water round invasion"* indicator.

The possible unification of the *"presence or absence indicators of organizations or social groups linked to wetland conservation"* and *"Number of Educational Institutions whose PRAES include the development of activities related to the wetland"* was discussed. However, it was concluded that they have different approaches and resources. The PRAES (Environmental Education Projects for Sustainability) programs focus on awareness activities with pedagogical strategies tailored for specific school ages. On the other hand, organizations focus on strengthening environmental awareness that is already internalized and their activities are segmented in terms of ages, scope and community engagement. While the importance of both indicators is recognized, it was clarified that their activities are sporadic and monitoring is not constant, making it difficult to establish long-term processes.

Hydrological Indicators:

At the onset of the qualification process, the focus is on determining the water-related objectives of each variable. This involves analyzing factors such as drought impact on biota, water supply analysis and other relevant considerations. The qualification of indicators is then directed towards those that can be more readily implemented with the community. When assessing the historical series, the significance of this information becomes apparent as it encompasses both the decrease and increase in flow over time. These historical data sets offer insights into the ongoing phenomena within the ecosystem.

During the qualification process for the water mirror and internal flows, it was determined that the water mirror can fluctuate depending on the season, whereas continuous internal flows indicate the sustained functionality of the wetland. It is also recognized as a highly significant factor within wetlands and one of the most sensitive to any changes that occur in their surroundings.

Management Indicators:

The analysis suggests that the indicator of "*the number of families that have adopted good management practices"* is more relevant than the "*success of the restoration, given the sustainability and permanence of the practices"*. This perspective is based on the premise that the adoption of good environmental practices by families will directly impact the state of the restoration efforts. The success of restoration efforts relies on sustained commitments from those involved in the processes. This same analysis is reaffirmed for the "*status indicator of protective fences"*, underscoring the pivotal role of human resources as mobilizers of the projects.

It is determined that if families are committed, they will be attentive and proactive regarding the state of the protective fences. It is also considered that prioritizing the number of people participating in various restoration activities is crucial, as the success of the restoration is seen as a consequence of their involvement.

Similarly, it is concluded that when assessing the "*status of the protective fences"*, their installation alone is insufficient. Without the commitment of the landowners, essential monitoring and maintenance would not be carried out. Therefore, the commitment of the people is deemed crucial.

Experiences are shared that allow us to conclude the importance of institutional presence in providing continuity to projects. Over time, it has been demonstrated that people recognize changes in land use, fostering confidence and credibility in implemented restoration programs.

The indicator of "*restoration success"* is considered to depend on the state of the protective fences. The strategy of protective fences allows for the care of the wetland ecosystem, emphasizing the importance of maintaining them in good condition.

During the classification and socialization process, the conclusion was reached that adding the "*indicator of conservation and restoration agreements"*, specifically targeting payments for environmental services, would be beneficial. This proposal stems from the success of numerous strategies employing this approach, which foster alliances between institutions and landowners. Moreover, it encompasses the ongoing training and monitoring activities conducted in the area. It is deemed to be of greater significance across most indicators, as the implementation of conservation and restoration agreements by more families leads to a broader coverage of strategic land. This alignment of interests and approaches benefits all stakeholders involved. It is believed that the enrichment of conservation and restoration agreements occurs with increased participation from stakeholders.

After this initial filtering process, the prioritized sub-indicators underwent further evaluation to ensure they meet criteria such as clarity, relevance to the community, monitorability and economic feasibility, as outlined in the methodological process.

A rating matrix was employed to assess the indicators based on the aforementioned parameters, resulting in a final list of selected indicators (Table 7)

Table 7. Selected indicators for monitoring once all classification filters have been completed

Indicator	Sub-Indicator
Management Indicators	Number of family members participating in various restoration activities. Restoration Success State of protective fences Conservation and restoration agreements—payment for environmental services
Landscape Indicators	Fragmentation % of natural coverage in the basin Management of impacts generated by direct action in the wetland
Hydrological Indicators	Presence/Absence of water mirror Increase /decrease in water level
Socio-Cultural Indicators	Presence/absence of spill contamination Management of production systems Food Security Presence of invasive species % of coverage of introduced species Loss of native biodiversity
Physical-Chemical Indicators of Water	Water temperature Ph Turbidity Dissolved Oxygen Nitrates Phosphates

Subsequently, the indicators were entered into the Kobo Toolbox software. This software allows not only the collection of data in the field but also the systematization of data by site. It carries a logical sequence of each collected indicator, providing permanent information for follow-up.

With the sites determined and the indicators prioritized, the pilot field test was applied, which is described below in the following paragraphs.

- ✓ ***Phase 3. Pilot testing Formulation of Participatory Monitoring and Management on Selected Indicators.***

The monitoring was conducted at six points, representing six distinct communities and water sources located both upstream and midstream within the basin. The selection criteria included: a) accessibility to the study area, b) community willingness to participate, c) involvement of educational institutions, d) participation of individuals across different age groups, including children, youth and adults and e) inclusion of rural aqueduct supply sources.

A preliminary workshop was conducted in each community to assess existing knowledge, introduce the monitoring method and establish work teams.

The roles assigned for the monitoring process were as follows: **Project Leader:** Responsible for overseeing the project and its direction. **Technical Assistant:** A professional tasked with managing and controlling the equipment for measurements, aiding in training and contributing to data collection. **Community Leader:** Representatives of the community who communicated community concerns and needs and advocated for organization and collaboration during workshops and monitoring activities. **Community:** community groups were formed to manage various aspects of the monitoring process, including maintaining schedules, ensuring availability of materials, fulfilling basic requirements, managing storage, ensuring safety and care of equipment and organizing completed formats and records. **Data Management Team:** This function was exclusively carried out by project team participants, focusing on processing and interpreting the data obtained for subsequent socialization.

For the collection of information for monitoring each indicator, an information collection protocol was developed. This protocol included details such as the indicator to be measured, necessary materials, method of measurement and frequency of measurement. To facilitate community understanding, this protocol was transformed into infographics.

Subsequently, the field phase was conducted with active participation from the community to address any questions related to the protocols for each indicator. Data collection involved the use of various equipment. For physical-chemical parameters, an oximeter (also measuring BOD), a conductometer, a pH meter and a turbidimeter were utilized. Additionally, an in-situ meter for nitrates, nitrites and hardness was employed. Flow measurements were conducted using both reel and manual methods, with a bucket equipped with a meter used for smaller flows. In the protective forest area, a tape measure was used along with the expertise of each of the inhabitants to calculate the forest's extent. For biological and biotic indicators, a checklist of various species presented in the study area needed to be compiled. Compared to the other parameters, the information was consolidated through questions posed to the community.

Below is the model formulated for the monitoring of each indicator and the tools designed to collect the information, according to the method selected for each (Table 8):

Table 8. Model of form for indicator monitoring, "x" are spected blank spaces to fill by community *in-situ*.

Management indicators					
Variable	Number of families that have adopted good environmental practices				
Description	Good Environmental Practices are actions that pretend to reduce negative environmental impact being provoked by productive processes, making use of simple and usable actions that can be used by everyone at workplaces and stablish changes on processes and daily activities, leading to increase commitment and results on improving in the environment				
Rating scale Score	Corresponding situation	Current	Month 1	Month 2	Month 3
5	Families that have adopted actions that contribute to diminish negative environmental impact, from applying of waste management, in-source separation, use of organic fertilizers and integration on Environmental Services Payments	x	x	x	x
4	Families integrated on Environmental Services Payments	x	x	x	x
3	Productive families that use sustainable processes (organic pass, protective areas enclosure and, sustainable stockbreeding)	x	x	x	x
2	Families that: use waste separation, identify and work with authorized waste managers/operators	x	x	x	x
1	Families that have no participation in any workshop, training or sensibilization and families that have not used any strategy related to wetland ecosystem attention.	x	x	x	x
Verifying methods	Pre-designed surveys, field days, participant observation, and site surveys of strategic places for measurements				

After the initial measurement of each parameter, a meeting was convened with the expert team to fine-tune the instruments being utilized with the community. This gathering uncovered some initial challenges:

Technical Challenges

In various monitoring points, not all variables are needed to be measured. The choice of variables and their measurement methods depends on the specific context. For instance, the water source in one community may originate from percolation without an initial flow, while in another, it may stem from a wetland with a flow. Additionally, vegetation coverage may vary, with some catchment areas with dense vegetation and others lacking any coverage at all.

Ensuring data and its sampling's reliability and consistency is another challenge, as well as maintaining monitoring over time.

On the other hand, it is necessary to consider the inclusion of other variables that were not found in the literature and were not evaluated by the experts. For instance, the issue of mass removal around water sources, which generates state problems for aqueducts, especially during winter, was identified. In this case, it was necessary to establish a protocol to determine the method of measurement of the mass removal indicator.

It was necessary to establish different protocols for biology because the list of species varies at each point according to the different altitudinal floors.

Adjustments were made to the measurement protocols according to any of the cases.

Administrative Challenges

It was necessary to establish a monitoring plan that allowed the measurement of the indicators in each of the contexts, considering those that could not be measured. For example, in the case of a wetland that was not lentic, the area of water mirrors could not be measured.

A major challenge is ensuring a project’s continuity in the communities. Empowering leaders in each of their roles is fundamental to ensuring sustainability.

The use of technology poses a challenge, particularly for spatial indicators that require technological processes beyond low-cost methods accessible to the community.

Education and leadership are essential for ensuring the sustainability of monitoring processes. Additionally, social appropriation of knowledge may be influenced by the level of education.

Conclusions

The complexity of wetland ecosystems is addressed in the study because of the diversity of indicators addressed in the study, underscoring the need for assessment of various dimensions, from physicochemical to socioeconomic and cultural indicators, which classification at different levels (management, monitoring, hydrological, biotic, physical-chemical, socio-economic) implies an organized structure for assessing multiple aspects of wetlands in an interdisciplinary way.

The community’s inclusion in the decision-making and monitoring process is fundamental because of the importance of active participation in data collection and analysis, depending on the role assignment of different community members, such as leaders and data management teams, which denotes a wide approach, promoting local appropriation of the project.

AHP methodology to rank indicators demonstrates a readiness to adjust and enhance approaches in line with the requirements and contributions of experts and local communities, whose participation plays a vital role in the project’s development, demonstrating a continuous improvement approach with constant feedback and reflection that contribute to the accuracy and relevance of selected indicators.

The utilization of technological tools, such as Kobo Toolbox for data collection and systematization, underscores the significance of efficiency and accessibility in the monitoring process. It enables further adjustments by applying it in a pilot field testing phase, validating the process and enabling further adjustments before the implementation on a larger scale.

Challenges during the pilot test's implementation involve adaptation of context in measurements, emphasizing the necessity of linking measurement protocols to depend on each community's specific characteristics. Technical challenges are related to variability in water sources and the incorporation of variables that were not considered. This underscores the significance of adapting monitoring approaches, addressing the unique characteristics of each context.

Administrative and sustainability challenges include monitoring planning and the imperative to sustain community interest and engagement over time. The sustainability of the project hinges on empowering local leaders and underscores the significance of education and leadership in guaranteeing the continuity of monitoring processes.

Finally, the challenges related to technology use in measurements, particularly for spatial indicators, are emphasized. It is suggested that the implementation of technologies may be expensive and inaccessible for some communities.

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