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Treatment wetlands in Embera indigenous communities (Colombia), are they Nature-based Solutions?

Andrea Martín-Dato [a], Julia Pérez [b], José M. López-Cózar [d], María José Rubial-Fernández [a], Felipe Valderrama [b], Miguel Martín [c], Diana Díaz [b], Andrés Velasco-Posada [a], María Sabater [b], Ester Gismero [a], Carmen Hernández-Crespo [c,*]

[a] Azentúa, Calle Claudio Coello 78, 4 planta, 28001, Madrid
[b] Fundación Humedales
[c] Instituto de Ingeniería del Agua y Medio Ambiente, Universitat Politècnica de València
[d] Fundación Global Nature

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ABSTRACT

The sustainable use and protection of water resources are urgently needed. Human activity and climate change are exacerbating water-related problems and worsening the quality of riparian and wetland ecosystems, rendering them unable to provide services which are basic to human well-being and socioeconomic development. The most affected communities are those that rely on natural aquatic environments, thus suffering the worst consequences of its degradation.

This is the case of the Colombian Embera indigenous people, whose populations have been forced to migrate, due to armed conflicts, to peripheral urban areas without access to safe water and sanitation. For this reason, the international cooperation project "Baña Do Bari" was set up to design and implement treatment wetlands (TWs) for the treatment of wastewater mainly produced in sanitary infrastructure, with the purpose of guaranteeing adequate living conditions and improved basic hygiene to indigenous communities. The sanitary infrastructure was designed collectively with the participation of the community.

In this paper, the above-mentioned project is analyzed to determine if its actions can be considered Nature-based Solutions (NBS) and to identify opportunities for improvement. To this end, the IUCN Global Standard for NBS and other technical criteria were used. The main results indicate that TWs built within the "Baña Do Bari" project can be considered a NBS according to the technical criteria used for self-assessment. Regarding the Standard, the project strongly resolves social challenges. The criteria that could be improved are mainly related to the collection of environmental data on the biodiversity conservation status in the area.

1. Introduction

Ecosystem services provided by biodiversity are essential for human well-being and their global economic value is estimated at USD 125-140 trillion per year. However, the rate of biodiversity loss is now at an unprecedent level in history, and costs of the ongoing degradation are estimated at USD 10-31 trillion per year [1]. Indeed, ecosystems are moving to critical thresholds which, if crossed, will result in persistent and irreversible, or very costly to reverse, changes to ecosystem structure, function and service provision [1]. Prioritizing actions aimed to recover habitats, ecosystems, biodiversity and its services is therefore a necessity, which has been recognized in different international agreements, such as Agenda 2030 [2], Aichi Goals [3], and the recent 15th Conference of the Parties (COP15) of the Convention on Biological Diversity [4].

Another major problem is the lack of access to safe water and sanitation for a large proportion of the world's population. According to the latest UN SDG report (2020) [5], 4.2 billion people worldwide still

* Corresponding author.
E-mail addresses: andrea.mdato96@gmail.com (A. Martín-Dato), julia.perez@fundacionhumedales.org (J. Pérez), jcozar@fundacionglobalnature.org (J.M. López-Cózar), mariajose.rubial@azentua.com (M.J. Rubial-Fernández), fvalde@fundacionhumedales.org (F. Valderrama), mmartin@hma.upv.es (M. Martín), diana.diaz@fundacionhumedales.org (D. Díaz), andres.velasco@azentua.com (A. Velasco-Posada), maria.sabater@fundacionhumedales.org (M. Sabater), ester.gismerogil@hotmail.com (E. Gismero), carhercr@upv.es (C. Hernández-Crespo).

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lacked safely managed sanitation, including 2 billion without basic sanitation, of whom 673 million practiced open defecation. In developed countries, this number is much lower but there still are populations without adequate sanitation infrastructure [6]. Furthermore, in these high rent countries many small villages use treatment systems based on activated sludge with extended aeration, a treatment that consumes an excessive amount of energy. Therefore, a paradigm shift is needed to achieve sanitation for all (SDG 6) in a truly sustainable way.

Nature-based Solutions (NBS) can help address these worldwide problems. In fact, many countries have committed to use NBS in their revised Nationally Determined Contributions (NBCs) [7]. Since the use of this term for the first time by the World Bank, in 2008, several definitions have been released by the European Commission and the International Union for Conservation of Nature (IUCN) [8]. However, these definitions were somewhat general and ambiguous, giving rise to an ongoing debate on the scope and types of interventions that can be classified as NBS [8,9]. To ensure a clear understanding of the concept, the IUCN developed the Global Standard for NBS (the Standard herein), which is intended to used by anyone working on the design, verification or scaling up of NBS [10]. Similarly, Sowińska-Świerkosz and García proposed core ideas and exclusion criteria (core ideas herein), based on official guidelines [10,11], and other literature [8]. Therefore, this list of core ideas and exclusion criteria can gather extra information, as it was formulated by integrating the principles of various bibliographic sources, both scientific and technical.

NBS have proven to be cost-effective solutions, presenting a cost benefit ratio higher than gray solutions for the same level of avoided damages [12]. Furthermore, NBS in the built environment contribute to the transition to a circular economy, provide diverse ecosystem services and confer resilience to the urban environment [13].

However, use and application of NBS are not so widespread. Barriers for NBS to scale-up are diverse: lack of knowledge by decision-makers, social uncertainty and lack of receptivity, being some of the most relevant [14]. To overcome these barriers, it is important to provide the right information at the right time to ensure that the technical solution adopted is successful [15]. Moreover, another key component for NBS success is how stakeholders engage with the citizens and integrate their views into the decision-making process [16]. Accordingly, governance can be considered as a driver for NBS technology adoption.

Treatment wetlands (TWs) are technologies implemented all over the world for the treatment of domestic wastewater of small/medium sized human settlements [17–19]. Aquatic macrophytes and the microbiota in their root systems metabolize organic matter and absorb some mineral nutrients from water. This process, considered to be one of the most crucial ecosystem services of water quality improvement (*i.e.*: regulation & maintenance of water quality), occurs spontaneously in natural wetlands, and is efficiently reproduced and enhanced in the TWs [19,20].

Recently, TWs have been classified as NBS technological units, described as blue/green technologies intended to provide specific features and services [9]. However, it can be hypothesized that TWs can be fully qualified as NBS if the Global Standard for NBS and other guiding criteria are followed in the design and implementation stages. To date, very few studies have addressed the application of such standards to verify the compliance of interventions with NBS requirements [7].

This study applies the Standard and core ideas to the design and implementation phases of a cooperation project aiming to provide sanitation to an indigenous community using TWs. The objective is twofold: on the one hand, to use the Standard and the core ideas as a self-assessment tool to achieve greater compliance with NBS requirements and, on the other hand, to provide examples of good practices in the application of the Standard, which can be used by anyone interested in the subject.

Table 1
Description of TWs implemented in the "Baña do Bari" project. Surface area is indicated in m^2.

Indigenous Community	Type of wastewater	Floating TW (m^2)	Renaturwat wetland		Total new wetland area (m^2)
			VF TWs (m^2)	FWS TWs (m^2)	
Tuis Tuis	Domestic	574	64	2500*	638
	Poultry farm	50	1.2		51.2
	Fish factory	42	12		54
Los Placeres	Domestic	198	24	20	242
Manantiales	Domestic	353	40	50	443

*Note: this is a previously existing lagoon with poor water quality, which is intended to be restored with the renatured effluent from Tuis Tuis' TW.

2. Materials and methods

2.1. Study area

Tierralta (Córdoba, Colombia) is an agricultural and cattle farming oriented municipality located in the High Sinú river region. With an average temperature of 29°C (84°F) and an annual rainfall between 1,675 and 3,500 mm, water resources are abundant in the region. Paramillo National Natural Park is located within Tierralta, one of the ancestral territories of the Embera Katío indigenous community. Due to social and political phenomena (armed conflicts and others), several communities living in this natural park were forced to migrate to peri-urban areas of the municipality. Small settlements were stablished in the villages of Tuis Tuis (8°03'21.6"N 76°06'08.7"O), at 72 masl (meters above sea level); Manantiales (8°03'26.6"N 76°04'45.8"O), at 96 masl; and Placeres (8°07'57.2"N 76°01'26.2"O), at 70 masl. Such new lands were selected by the communities because of their agricultural potential to support a subsistence economy model followed by productive projects aiming at local markets. However, despite the natural abundance of water resources, they do not have access to drinking water or basic sanitation services.

Embera communities in Tuis Tuis, Manantiales and Placeres have an approximate total of 410 inhabitants, currently following traditional indigenous lifestyles as well as some other traditions they established themselves.

The cooperation project evaluated in this study (Baña do Bari project) is intended to provide safe drinking water and sanitation for the three communities with the implementation of NBS, while focusing on the social aspects.

We proposed solar disinfection technology (SODIS) to improve access to drinking water. To address sanitation and wastewater treatment, codesign and construction of sanitation infrastructure (toilets, showers and sinks), and treatment wetlands (TWs) were projected.

2.2. Project description

In this project, free water surface flow (FWS) wetlands with floating macrophytes (floating TWs herein) collected from local aquatic ecosystems and vertical flow (VF) TWs have been projected and built for wastewater treatment. FWS TWs were selected based on the simplicity of their construction and operation[21], in which both foundations, Fundación Humedales and Global Nature, have extensive previous experience[1].These TWs will treat the wastewater produced by the communities (Tuis Tuis, Manantiales and Los Placeres) as well as a poultry farm and a small fish farm in Tuis Tuis. The treatment system

[1] https://fundacionhumedales.org/2022/10/28/filtros-verdes-latinoamerica/https://fundacionhumedales.org/2022/12/07/filtros-verdes-colombia/

Fig. 1. Scheme of the sanitation system projected and built in Embera Katío indigenous communities and pictures of the functional components.

consists of pre-treatment and primary treatment units (septic tanks), secondary treatment (floating TWs), and tertiary or upgrading treatment (VF TWs followed by FWS TWs to renaturalize treated water) (Table 1, Fig. 1).

VF TWs include a novel advanced treatment tested in LIFE Renaturwat project. The novelty is based on the integration of circular economy principles into the urban water cycle. In Drinking Water Treatment Plants (DWTPs), a solid waste is produced in the physiochemical treatment process, referred to as drinking water treatment sludge (DWTS). The cost of managing such sludge could be reduced by some feasible valorization. This consists of using its adsorbent capacity to reduce the concentration of phosphorus present in wastewater. It was proposed to use sludge as reactive porous media in VF TWs, thus giving added value to the DWTS, by transforming it into raw material. In a pilot experience where DWTS was used in VF TWs for upgrading treated wastewater, it was demonstrated that the proposed solution reduced the load of organic matter, nutrients, pathogens, and emerging organic contaminants remaining in the secondary effluent [22]. This upgraded wastewater treatment favors the later reuse of reclaimed wastewater for irrigation of crops cultivated by the indigenous communities. Moreover, vegetation growing in TWs will be composted when it finishes its growth season and starts to die, thus obtaining an organic amendment to be reused in crop lands. Therefore, the project can be considered a good example of circularity too

The “Baña do Bari” project, constitutes a fully sustainable water treatment process because it does not require energy sources to operate (*i.e.*, no electricity sources, particularly from biomass fuels). Water quality at the effluent is expected to meet the requirements to be reused for irrigation of ornamental plants crops and other agricultural uses.

Moreover, if such a TW is constructed and supplemented by a free surface flow water body, effluent re-naturalization can be attained, thus improving aquatic biodiversity by increasing the number of aquatic invertebrates and promoting the colonization of the TW system of different species of amphibians, reptiles, fish, birds, and land insects. Both actions provide additional environmental services and benefits, such as landscape integration and marsh-like habitat generation [23].

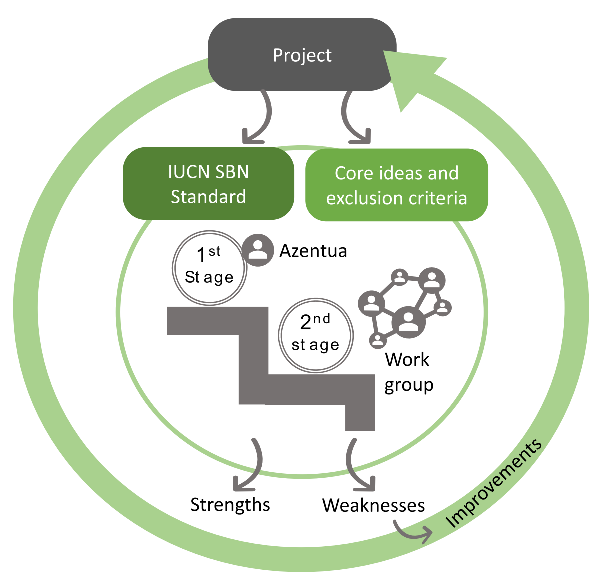

Fig. 2. Scheme of the project evaluation according to the IUCN SBN standard and the core ideas proposed by [8].

2.3. Methodology for self-assessment of the project

The project evaluated in this study proposed the use of NBS to provide a sanitation system to indigenous communities. As part of the quality control of the project, evaluation of the proposed design of NBS in accordance with the Global Standard for NBS [10] and core ideas for NBS [8] was planned. To this end, a sequential procedure with feedback to improve the project was followed (Fig. 2). The steps of the procedure are described below.

Preliminary preparation

To determine if the project adequately complies with the Global Standard, it was necessary to join the "IUCN Global Standard for NBS Users Group" by completing a survey. Subsequently the IUCN provides the required self-assessment tool, explained in more detail hereafter.

The Standard consists of 8 criteria, each with a set of indicators (28 in total). The criteria are as follows:

Criterion 1: NBS effectively address societal challenges.

Criterion 2: Design of NBS is informed by scale.

Criterion 3: NBS result in a net gain to biodiversity and ecosystem integrity.

Criterion 4: NBS are economically viable.

Criterion 5: NBS are based on inclusive, transparent, and empowering governance processes.

Criterion 6: NBS equitably balance trade-offs between achievement of their primary goal(s) and the continued provision of benefits.

Criterion 7: NBS are managed adaptively, based on evidence.

Criterion 8: NBS are sustainable and mainstreamed within an appropriate jurisdictional context.

The self-assessment tool allows users to calculate the match percentage of their intervention with respect to the eight above-mentioned criteria, and therefore determine if the intervention can be considered a NBS according to the IUCN.

Initial assessment (1st Stage)

Once the preliminary tasks have been completed, a first approach to align the project to the Standard was carried out by Azentúa (Fig. 2). This approach ensures that the Standard is understood, the technical and economic aspects of the project are covered, and the environmental and social aspects are correctly integrated prior to the stakeholder engagement.

The documentation compiled and analyzed included the TWs and associated interventions (*i.e.*, infrastructures, cost-effective analysis, etc.). The natural environment of the study area and the socio-environmental impact of TWs in each community were also considered. The inclusion of the Embera indigenous people was verified (*i.e.*, how participatory, and inclusive the project is), including meetings, management of complaints/recommendations and co-design with the local communities, among others. Finally, financial information was compiled, as well as the plan or strategy for outreach of the project's progress/success.

Once the information was gathered, analyzed, and harmonized, the self-assessment tool (hereinafter referred to as the Tool) could be used to assess the project through the analysis of the Standard criteria. The Tool, in the form of an Excel spreadsheet, enables users to identify the extent to which their intervention adheres to individual indicators. For each indicator, there are four scores of qualifications: "strong", "adequate", "partial" or "insufficient", depending on whether the design of an intervention meets the qualifying requirements. To do this, the tool provides a guiding question for each indicator, and a description of the differences between the four scores. Then, it is necessary to write a rationale of the assessment with information from the project to justify the chosen score, together with a reference to the documents that support the rationale. If necessary, recommendations, opportunities and challenges can also be included to improve the score of an indicator.

Subsequently, a match percentage is calculated for each criterion. This percentage is calculated by giving a value to each score (strong = 3, adequate = 2, partial = 1 and insufficient = 0). When the indicators of a criterion have their score assigned, the values of the indicators are added to obtain the total score of the criterion. After this step, the resulting score of the criterion is divided by its maximum score to find the percentage of match (*i.e.*, if the criterion has 4 indicators, the maximum score will be 12, and if the criterion score is 9, the percentage will be 75%). In this way, the scores are standardized, and each criterion weighs the same. They are also color coded (see Table 2).

Table 2
Relationship between the color code, the percentage match, the rating match, and the self-assessment output, adapted from [10].

Color	Related value	Match percentage	Indicator score	Output
1.0	3	≥75	**Strong**	Intervention adheres to the IUCN Global Standard for NBS.
0.7	2	≥50 & <75	**Adequate**	
0.5	1	≥25 & <50	**Partial**	
0.2	0	<25%	**Insufficient**	Intervention does not adhere to the IUCN Global Standard for NBS.

Finally, the percentages of the criteria are averaged to find an overall percentage match and an overall category match for the project. However, regardless of the overall percentage match result, if the project achieves a score of "insufficient" (<25%) with respect to any of the criteria, then it does not conform to the Standard.

Stakeholder assessment (2nd Stage)

The last stage consists of a collaborative application of the Standard by a multidisciplinary group formed by part of the project's stakeholders (Fig. 2). This integrated evaluation aimed to consider the different partakers' perspectives on the final score.

The stakeholders' assessment was carried out over a two-days' workshop prepared and coordinated by Azentúa, where all partners involved shared their scores and discussed them within the group.

Each participant applied the criteria of the Standard by filling in an *ad hoc* form to facilitate and clarify the choice of scores (*i.e.*, it included a summary and extended description of the scores, information needed to support/verify the assigned score, and others). Each stakeholder had the option of accompanying the chosen score with its own verification proof and was free to make its own recommendations of improvement.

The stakeholders involved in the joint application of the Standard are:

- **Polytechnic University of Valencia (UPV)**: Spanish university, developer of the innovative RENATURWAT technology.
- **Fundación Global Nature (FGN)**: Spanish NGO dedicated to the protection of nature. General coordinator of the "Baña Do Bari" project.
- **Fundación Humedales (FH)**: Colombian NGO dedicated to the conservation and participatory management of aquatic ecosystems. Local coordinator of the "Baña Do Bari" project.
- **Urrá S.A. (U)**: Colombian company currently in charge of the Alto Sinú Hydroelectric Project. The "Baña Do Bari" project is linked to its Corporate Social Responsibility, which is why it co-finances it and its indigenous affairs team supports the communities.
- **Azentúa (A)**: Spanish environmental and social engineering firm. Responsible for applying the Standard in the "Baña Do Bari" project, and for carrying out the Socio-Environmental Impact Studies.

The stakeholders who responded to the questionnaire are the same project partners. It is a self-assessment evaluation, indeed. To avoid possible bias or conflict of interest, the premise was that each participant must answer the questions on each of the 28 indicators objectively. Initially, it was considered that some indigenous people would also answer the questionnaire. However, this was not feasible due to its length and complexity, partly because of language barriers and the technical content of the questionnaire. Nevertheless, the perception of the host community on the infrastructures built druing the project was recorded qualitatively.

Table 3
Average scores assigned by criterion and stakeholders. The last column indicated the overall project match (%) and the last rows indicate the average, standard deviation, and coefficient of variation for each criterion and the overall match. The color code of the percentages is the same as that shown in Table 2, which indicates the four-score of qualification: strong (dark green), adequate (light green), partial (orange) or insufficient (red). U: Urrá S.A.; A: Azentua.

	Criteria match (%)								
Participants	C1	C2	C3	C4	C5	C6	C7	C8	Overall match (%)
UPV1	100	78	50	75	100	89	89	78	82
UPV2	89	78	58	50	100	89	56	78	75
FGN1	78	78	33	67	87	100	100	100	80
FH1	78	89	42	83	93	67	56	67	72
FH2	100	89	50	75	93	100	78	67	81
FH3	67	67	67	67	60	56	78	100	70
U1	78	78	75	92	93	89	100	100	88
A1	89	78	50	58	87	67	67	67	70
Average (%):	85	79	53	71	89	82	78	82	77
Std. variation.:	11,02	6,66	12,46	12,5	11,99	15,65	16,67	14,63	6,21
Coeff variation (%)	13	8	23	18	13	19	21	18	8

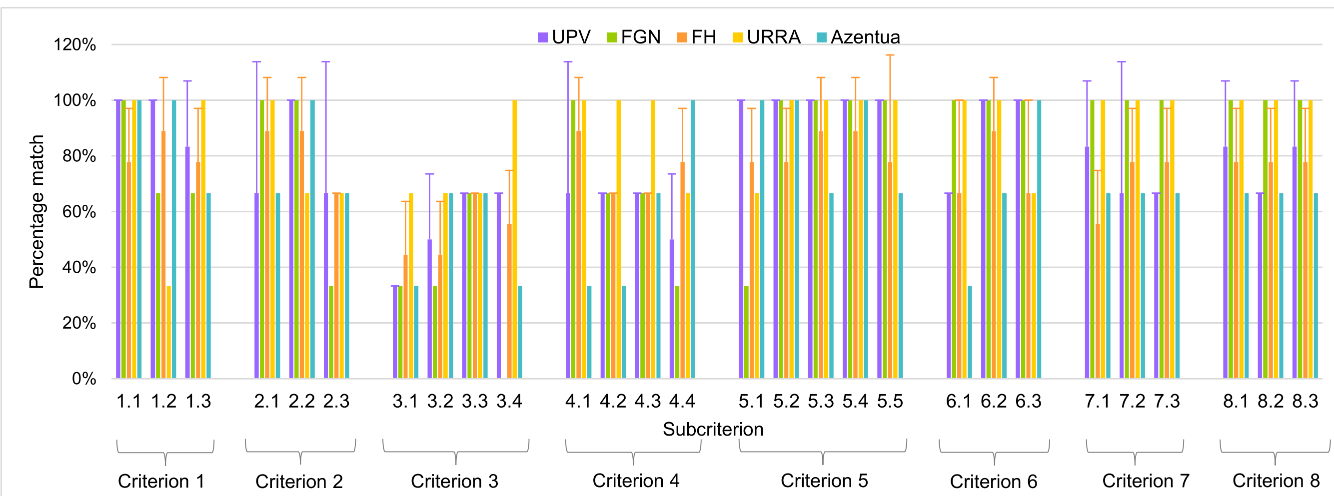

Fig. 3. Percentage match for each sub-criterion and stakeholder.

2.4. Statistical analysis

Statistical analyses were performed using Statgraphics Centurion 18 software. The influence of the stakeholders and criteria on the score obtained were assessed using parametric tests (ANOVA) if normality was satisfied, if not, nonparametric tests (Kruskal Wallis) were used. Statistical significance was indicated by a probability of type I error of 5% or less ($p \leq 0.05$).

3. Results and discussion

3.1. IUCN SBN standard

This section summarizes the overall project score according to the stakeholder assessment process. As previously mentioned, the second stage of the process took place in a two-days' workshop and each participant took between 6 to 8 hours to fill out its *ad hoc* form. Table 3 shows the project's percentage matches, resulting from scoring of individual criteria and Fig. 3 shows the detail of sub-criterions.

When analyzing the match percentages of the project with the 8 criteria (Table 3), the stakeholders differ in the scores assigned to each criterion, even those within the same entity (in the case of the UPV and FH). However, it should be noted that most of the percentage matches have been given a "strong" score, and no stakeholder has scored the project as "insufficient" in any of the 8 criteria (and even when they did for some of the indicators within a criterion, the total criterion score is still greater than "insufficient"). Therefore, the stakeholders have individually concluded that the "Baña Do Bari" project is aligned to and compliant with the Standard.

The statistical analysis indicated that the scores assigned by Azentua and Urrá S.A. are significantly different from each other ($p<0.05$), while the other participants did not differ among them nor with Azentua and Urrá. Azentua assigned the lowest average score (70%) and Urrá the highest (88%), the others remained in a similar intermediate position between them (74-80%). Although the overall score was adequate or better, the results show the value of conducting evaluations in a multidisciplinary working group, as weaknesses can be detected and opportunities for improvement can be proposed.

Looking at criteria, the third one (C3), related to a net gain to biodiversity and ecosystem integrity, obtained a score significantly lower than the others ($p<0.05$), whereas the others did not differ significantly among them ($p>0.05$).

The main reason for the lower score for C3 is related to the area of the treatment wetlands. Although they can enhance biodiversity, and have been designed taking this into account, their relatively small size (222 – 743 m^2, depending on the Community) is considered insufficient to significantly influence the biodiversity in the whole ecosystem, but rather on a much more local scale. Additionally, the information about the biodiversity in the area is scarce, the evaluation performed in the project was based on general information of vegetation cover and land uses at a regional scale. The project did not plan monitoring of the impact on the receiving environment. However, identifying this weakness led to propose studies on biodiversity and the impact on the receiving waters. The monitoring proposed is qualitative and using

Table 4
Core ideas and exclusion criteria proposed by Sowińska-Świerkosz & García [8] (left column) and description of how the project covers them (right column "Project Embera TWs").

CORE IDEAS		Project Embera TWs
1	Actions inspired and powered by nature.	TWs mimic processes occurring in natural wetlands. These natural processes treat wastewater, removing organic matter, nutrients, and pathogens.
2	Actions confronting challenges.	• Sanitation and wastewater treatment for indigenous communities which are environmentally and economically sustainable. • Raise awareness and help the indigenous communities become accustomed to using toilets.
3	Actions providing multiple benefits.	• The stream will no longer receive wastewater without treatment, which will benefit Embera's downstream users. • Renaturalization of wetlands will improve aquatic biodiversity and contribute to the water's disinfection.
4	Actions with a certain level of effectiveness and efficiency.	TWs constitute cost-effective technology. Many studies demonstrate their efficiency in terms of physiochemical and biological water quality improvement.
EXCLUSION CRITERIA		**Project Embera TWs**
1a	Lack of functioning ecosystems.	Embera's TWs represent a functioning ecosystem. Vegetation, bacteria, and other living organisms, such as aquatic invertebrates, amphibians, reptiles and even birds will colonize the newly created ecosystem.
1b	Random actions.	The project addresses the sanitation of three indigenous communities. It aims to become a benchmark for Colombia and its neighboring countries. This will be the focus of the project's dissemination.
2a	Post-implementation goals.	The project aims to solve the stream's water pollution problem which is caused by the open practice of the Embera communities defecating there. It seeks to make them aware that this practice is not safe either for themselves or for the stream's downstream users.
2b	Negative/No impact on biodiversity.	The impact on biodiversity will be positive, especially in the renaturalization of wetlands and the receiving bodies of water.
3a	Same benefits as gray infrastructure alone.	Embera's TWs provide more benefits than equivalent gray infrastructure, such as habitat and biodiversity enhancement, carbon sequestration, energy savings, compostable biomass, and local jobs.
3b	Unfair distribution of benefits.	The benefits will be received by their own communities, but also by the users downstream.
4a	\`Copy-paste' implementation approach.	Embera's sanitation system, by means of communal baths, has been designed and adapted to their customs, following a process of consultation and participation with the community. TWs have also been adapted to their situation and their surroundings.
4b	Top-down governance model.	Embera's community has been engaged from the beginning, actively participating in all decisions and design phases.
4c	Static management approach.	The project has foreseen a monitoring period after its implementation, to ensure success. FH will check that Embera's communities effectively use the implemented solutions and that they understand how to manage them properly, how to benefit effectively from them, and how to make appropriate changes when a malfunction is detected.
4d	Financial expenses disproportionate to benefits.	The proposed solution is cost-effective.
4e	\`Point-scale' approach.	The project will benefit Embera's communities but also downstream users, and more communities if the project becomes a referent for other communities in Colombia and/or other countries. The monitoring period is to check the actual use of the implemented solutions by visiting the communities, but the receiving waters downstream also needs to be monitored.

simple, low-cost measurements, such as Secchi disk measurements, visual aspect of the receiving environment, or observation of aquatic invertebrates. This monitoring was proposed for the long-term, as a way of verifying whether the communities use and maintain the sanitation systems appropriately.

Moreover, it can be observed that criteria 1 and 5, although not significantly different from criteria 2, 4, 6 to 8, were rated by all stakeholders as "strong", except by participant 3 from FH who only assigns an "adequate" rating. This means that the major strengths of the project (on average for all stakeholders) are "inclusive, transparent and empowering governance", which rank in first place, and "societal challenges". Thus, the application of the IUCN Standard has served as a tool to identify the project's major strengths (criterion 5 and 1) and its major weakness (criterion 3) (Tables S1 and S2).

Other study which evaluated the alignment of 22 coastal NBS [7] have obtained an overall match significantly lower (partial) than that obtained in this study (strong). Probably, the lower match is obtained because the interventions have been evaluated after being implemented. This highlights the convenience of using the Standard at earlier stages (design stage) when improvements are still feasible.

These authors discussed about the desirability of adapting the Standard criteria to local contexts for an improved fit [7]. The results obtained in this study support this suggestion. In this case, the criteria related to biodiversity gain was poorly rated because of the localized influence of the intervention. However, if the biodiversity enhancement is compared to the absence-of-actions scenario, it would have scored better. In other words, if the criteria can be contextualized in each case, in general, they would be better aligned with the Standard purposes. Nevertheless, as commented before, checking against the Standard allowed identifying opportunities for improvement, such as the proposal of monitoring adapted to local conditions, not foreseen in previous phases of project conceptualization.

In addition, it would be highly desirable to have a simple questionnaire, which includes the main aspects of the criteria, so that it could be easily answered by the end users, in order to complement the self-assessment with their perception. In Baña Do Bari project it was not possible to fully adapt the questionnaire for its application to indigenous communities because of language barriers, technical complexity of the Standard and resistance to abstract thinking from the communities. Instead, a qualitative assessment of their perception was applied to confirm that they are satisfied with the services provided by the infrastructures and use them properly on a daily basis.

3.2. Core ideas and exclusion criteria application

As a complement to the Standard, the project was checked against the core ideas and exclusion criteria proposed in [8]. The results of this screening are presented in Table 4, in which the core ideas and exclusion criteria are indicated together with the description of how the project covers them. The conclusion is that the project meets the core ideas and significantly departs from the exclusion criteria, therefore this second assessment confirms that the TWs built in the project can be considered a NBS.

The core ideas summarize the main requirements to be met by the

NBS. As can be seen from the Table 4, this is a comprehensive list but significantly simpler and quicker to check than the Standard, which requires much more time and in-depth knowledge of the project.

Therefore, these core ideas could be used to collect the perception of external stakeholders and could even be answered by non-experts. Whereas the Standard is more recommended to detect SWOT and to be used by agents who know the project well and have a technical profile.

4. Conclusions

This study aimed to assess how aligned the project "Baña Do Bari" is with the Global Standard for NBS and core ideas for NBS proposed by other authors, to identify the strengths, threats, weaknesses, and opportunities for improvement.

The application of the IUCN Global Standard for NBS to evaluate the "Baña Do Bari" project has allowed implementing organizations to understand whether the infrastructure included in its implementation could be considered NBS, to comprehend in detail its strengths and weaknesses, and consequently to extract lessons learned. It could be said that there are other simpler and faster tools which could have been used, such as the also applied "Core ideas and exclusion criteria", but these are less exhaustive when it comes to identifying areas for improvement. Instead, they could be used to collect the perception of external stakeholders and could even be answered by non-experts.

The Standard has also allowed an in-depth review of the actions developed during the project, helping us to corroborate that environmental, social, and economic challenges in the project's context have been addressed in an appropriate way. From this point of view, the self-assessment tool of the Standard is a useful guide to ensure a correct project's formulation, implementation, and results dissemination.

It is also worth noting the difficulties the project encountered in integrating different stakeholders in the implementation of the Standard, especially the suppliers of goods and services and the end users of the infrastructure. Therefore, it is worth trying to bring the self-assessment tool closer to the stakeholders, representatively assessing the degree of agreement/disagreement of the participants. A simpler and adapted survey, such as the Core ideas could be useful in this sense. Nevertheless, an adapted language, picture-based even, would be recommendable. To overcome this shortcoming, in this project, special attention was given to qualitatively assessing the perception of indigenous communities. They were satisfied with the services offered by the project and with the infrastructure built, as they were always involved. They have understood the convenience of using blue/green infrastructure, and they use them with pleasure every day.

The main conclusion is that the project's methodology and implementation adequately aligned to the Standard and the "Core ideas and exclusion criteria", with the criterion related to biodiversity gain being the one with the most room for improvement.

The project also integrates the principles of circular economy through the valorization of three waste flows (DWTS, wastewater and vegetation biomass). It therefore represents an example of how NBS contribute to the transition towards a circular economy.

The results obtained from the self-assessment and the proposed recommendations may be used as reference for future projects that wish to apply the Standard. Indeed, the authors strongly recommend applying the IUCN tool during the design phase, to detect potential weaknesses at the very early stage and avoid potential impacts on ecosystem services and socio-economic-cultural systems later. Having real case studies such as the one presented in this paper will undoubtedly help others on their journey towards deciding which NBS adopt and implement.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.nbsj.2023.100074.

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