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Supplemtary material

Assessing sustainability in rural water supply systems in developing countries using a novel tool with Multi-Criteria Analysis: Supplementary material

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1. Detailed explanation and results of the analytic hierarchy process method

The application of the Analytic Hierarchy Process method (AHP) to determine the weights of the different attributes and establish their importance in the sustainability of rural water supply systems followed the stages and procedures recommended by Saaty [1]. Thus, the overall goal of the process was defined as "the evaluation of the sustainability of a rural water supply system." Table S1 provides the attributes to be compared in the evaluation that were obtained from an extensive literature review.

Table S1. Overall goal and attributes.

Overall goal	Attributes
Sustainability of rural water supply systems	1. Population characteristics
	2. Users acceptability
	3. Accountability and transparency
	4. Collective action
	5. Conflicts
	6. Policies, rules, and norms
	7. Administration, operation, and maintenance
	8. Post-construction support
	9. Access
	10. Appropriateness
	11. Infrastructure
	12. Reliability
	13. Water quality
	14. Financial knowledge
	15. Funding
	16. Risks to service provision
	17. Environmental impact of technology

An evaluation matrix containing the 17 criteria was prepared to assess the attributes according to their importance to achieve the overall goal. Using this evaluation matrix, researchers consensually expressed their preference for one attribute over another in each pair. For this, the nine point scale proposed by Saaty [1] (see Table S2) was used. A value of nine was assigned to an attribute if its

importance over the other was absolute, while the other attribute got the inverse (1/9). A value of one was assigned if the two attributes being compared were equally important [1]. The evaluation matrix, which includes the numerical values given by the researchers to determine the contribution of each attribute to the sustainability of a rural water supply system, is shown in Table S3.

Table S2. Fundamental scale.

Intensity of importance on an absolute scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment strongly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is strongly favored, and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals	If activity *i* has one of the above numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	
Rationals	Ratios arising from the scale	If consistency were to be forced by obtaining *n* numerical values to span the matrix

Source: Saaty [1].

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Table S3. Evaluation matrix.

Evaluation matrix (pairwise comparison matrix)																	
Attributes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1.00	0.33	3.00	3.00	3.00	3.00	3.00	3.00	0.33	0.33	0.33	0.33	0.33	5.00	3.00	1.00	9.00
2	3.00	1.00	3.00	1.00	3.00	3.00	1.00	3.00	1.00	0.33	1.00	1.00	0.20	5.00	3.00	0.33	7.00
3	0.33	0.33	1.00	0.20	0.33	0.20	0.33	1.00	0.20	0.14	0.20	0.14	0.11	3.00	0.33	0.20	3.00
4	0.33	1.00	5.00	1.00	3.00	3.00	1.00	3.00	0.33	0.20	1.00	1.00	0.33	3.00	3.00	1.00	7.00
5	0.33	0.33	3.00	0.33	1.00	3.00	1.00	3.00	0.33	0.20	0.33	0.33	0.33	3.00	3.00	0.33	3.00
6	0.33	0.33	5.00	0.33	0.33	1.00	0.33	1.00	0.20	0.14	0.20	0.20	0.11	1.00	0.33	0.20	3.00
7	0.33	1.00	3.00	1.00	1.00	3.00	1.00	3.00	0.33	0.33	0.33	1.00	0.20	3.00	3.00	0.33	5.00
8	0.33	0.33	1.00	0.33	0.33	1.00	0.33	1.00	0.11	0.11	0.20	0.33	0.11	0.33	0.33	0.20	3.00
9	3.00	1.00	5.00	3.00	3.00	5.00	3.00	9.00	1.00	0.33	1.00	1.00	0.33	3.00	1.00	1.00	9.00
10	3.00	3.00	7.00	5.00	5.00	7.00	3.00	9.00	3.00	1.00	1.00	3.00	1.00	5.00	5.00	1.00	7.00
11	3.00	1.00	5.00	1.00	3.00	5.00	3.00	5.00	1.00	1.00	1.00	3.00	1.00	5.00	0.33	1.00	9.00
12	3.00	1.00	7.00	1.00	3.00	5.00	1.00	3.00	1.00	0.33	0.33	1.00	3.00	3.00	1.00	0.33	5.00
13	3.00	5.00	9.00	3.00	3.00	9.00	5.00	9.00	3.00	1.00	1.00	0.33	1.00	7.00	1.00	3.00	9.00
14	0.20	0.20	0.33	0.33	0.33	1.00	0.33	3.00	0.33	0.20	0.20	0.33	0.14	1.00	3.00	0.20	5.00
15	0.33	0.33	3.00	0.33	0.33	3.00	0.33	3.00	1.00	0.20	3.00	1.00	1.00	0.33	1.00	0.33	5.00
16	1.00	3.00	5.00	1.00	3.00	5.00	3.00	5.00	1.00	1.00	1.00	3.00	0.33	5.00	3.00	1.00	7.00
17	0.11	0.14	0.33	0.14	0.33	0.33	0.20	0.33	0.11	0.14	0.11	0.20	0.11	0.20	0.20	0.14	1.00
$\sum$	22.64	19.34	65.67	22.01	33.00	57.53	26.87	64.33	14.29	7.01	12.24	17.21	9.65	52.87	31.53	11.61	97.00

Note: 0.11 = 1/9; 0.14 = 1/7; 0.20 = 1/5; 0.33 = 1/3

Subsequently, the normalized matrix was prepared. The values in this matrix were obtained by dividing each component of the evaluation matrix by the sum of each column in this matrix (last row of the evaluation matrix). Then the priority vector (Eigen vector) was obtained. This vector was determined using the simple average of each row of the normalized matrix and it defines the weight that corresponds to each attribute with respect to the overall objective [1]. The normalized matrix and the priority vector appear in Table S4.

The final step was the assessment of the researchers' judgement consistency. This consistency was checked using the Consistency Ratio (CR). In an evaluation matrix with n higher than five, consistency is considered acceptable when the CR is higher than 10%. To obtain the CR it is necessary to determine the column matrix. The column matrix is formed by the product between the original matrix (Paired comparison matrix or evaluation matrix) and the Priority vector [1].

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Table S4. Normalized matrix and Priority vector.

Attri-butes	Normalized matrix																	Priority vector
1	0.04	0.02	0.05	0.14	0.09	0.05	0.11	0.05	0.02	0.05	0.03	0.02	0.03	0.09	0.10	0.09	0.09	0.06
2	0.13	0.05	0.05	0.05	0.09	0.05	0.04	0.05	0.07	0.05	0.08	0.06	0.02	0.09	0.10	0.03	0.07	0.06
3	0.01	0.02	0.02	0.01	0.01	0.00	0.01	0.02	0.01	0.02	0.02	0.01	0.01	0.06	0.01	0.02	0.03	0.02
4	0.01	0.05	0.08	0.05	0.09	0.05	0.04	0.05	0.02	0.03	0.08	0.06	0.03	0.06	0.10	0.09	0.07	0.06
5	0.01	0.02	0.05	0.02	0.03	0.05	0.04	0.05	0.02	0.03	0.03	0.02	0.03	0.06	0.10	0.03	0.03	0.04
6	0.01	0.02	0.08	0.02	0.01	0.02	0.01	0.02	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.02	0.03	0.02
7	0.01	0.05	0.05	0.05	0.03	0.05	0.04	0.05	0.02	0.05	0.03	0.06	0.02	0.06	0.10	0.03	0.05	0.04
8	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.03	0.01
9	0.13	0.05	0.08	0.14	0.09	0.09	0.11	0.14	0.07	0.05	0.08	0.06	0.03	0.06	0.03	0.09	0.09	0.08
10	0.13	0.16	0.11	0.23	0.15	0.12	0.11	0.14	0.21	0.14	0.08	0.17	0.10	0.09	0.16	0.09	0.07	0.13
11	0.13	0.05	0.08	0.05	0.09	0.09	0.11	0.08	0.07	0.14	0.08	0.17	0.10	0.09	0.01	0.09	0.09	0.09
12	0.13	0.05	0.11	0.05	0.09	0.09	0.04	0.05	0.07	0.05	0.03	0.06	0.31	0.06	0.03	0.03	0.05	0.08
13	0.13	0.26	0.14	0.14	0.09	0.16	0.19	0.14	0.21	0.14	0.08	0.02	0.10	0.13	0.03	0.26	0.09	0.14
14	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.05	0.02	0.03	0.02	0.02	0.01	0.02	0.10	0.02	0.05	0.02
15	0.01	0.02	0.05	0.02	0.01	0.05	0.01	0.05	0.07	0.03	0.25	0.06	0.10	0.01	0.03	0.03	0.05	0.05
16	0.04	0.16	0.08	0.05	0.09	0.09	0.11	0.08	0.07	0.14	0.08	0.17	0.03	0.09	0.10	0.09	0.07	0.09
17	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01
	1.00	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

Evaluation matrix																		Priority vector		Column matrix
1.00	0.33	3.00	3.00	3.00	3.0	3.00	3.00	0.33	0.33	0.33	0.33	0.33	5.00	3.00	1.00	9.00		0.06		1.25
3.00	1.00	3.00	1.00	3.00	3.00	1.00	3.00	1.00	0.33	1.00	1.00	0.20	5.00	3.00	0.33	7.00		0.06		1.29
0.33	0.33	1.00	0.20	0.33	0.20	0.33	1.00	0.20	0.14	0.20	0.14	0.11	3.00	0.33	0.20	3.00		0.02		0.33
0.33	1.00	5.00	1.00	3.00	3.00	1.00	3.00	0.33	0.20	1.00	1.00	0.33	3.00	3.00	1.00	7.00		0.06		1.11
0.33	0.33	3.00	0.33	1.00	3.00	1.00	3.00	0.33	0.20	0.33	0.33	0.33	3.00	3.00	0.33	3.00		0.04		0.72
0.33	0.33	5.00	0.33	0.33	1.00	0.33	1.00	0.20	0.14	0.20	0.20	0.11	1.00	0.33	0.20	3.00		0.02		0.37
0.33	1.00	3.00	1.00	1.00	3.00	1.00	3.00	0.33	0.33	0.33	1.00	0.20	3.00	3.00	0.33	5.00		0.04		0.87
0.33	0.33	1.00	0.33	0.33	1.00	0.33	1.00	0.11	0.11	0.20	0.33	0.11	0.33	0.33	0.20	3.00		0.01		0.29
3.00	1.00	5.00	3.00	3.00	5.00	3.00	9.00	100	0.33	1.00	1.00	0.33	3.00	1.00	1.00	9.00	X	0.08	=	1.60
3.00	3.00	7.00	5.00	5.00	7.00	3.00	9.00	3.00	1.00	1.00	3.00	1.00	5.00	5.00	1.00	7.00		0.13		2.70
3.00	1.00	5.00	1.00	3.00	5.00	3.00	5.00	1.00	1.00	1.00	3.00	1.00	5.00	0.33	1.00	9.00		0.09		1.77
3.00	1.00	7.00	1.00	3.00	5.00	1.00	3.00	1.00	0.33	0.33	1.00	3.00	3.00	1.00	0.33	5.00		0.08		1.55
3.00	5.00	9.00	3.00	3.00	9.00	5.00	9.00	3.00	1.00	1.00	0.33	1.00	7.00	1.00	3.00	9.00		0.14		2.65
0.20	0.20	0.33	0.33	0.33	1.00	0.33	3.00	0.33	0.20	0.20	0.33	0.14	1.00	3.00	0.20	5.00		0.02		0.49
0.33	0.33	3.00	0.33	0.33	3.00	0.33	3.00	1.00	0.20	3.00	1.00	1.00	0.33	1.00	0.33	5.00		0.05		0.96
1.00	3.00	5.00	1.00	3.00	5.00	3.00	5.00	1.00	1.00	1.00	3.00	0.33	5.00	3.00	1.00	7.00		0.09		1.79
0.11	0.14	0.33	0.14	0.33	0.33	0.20	0.33	0.11	0.14	0.11	0.20	0.11	0.20	0.20	0.14	1.00		0.01		0.17

Then λ_{max} was calculated as the sum of all the elements that comprise the column matrix (Equation S1)

$$\boldsymbol{\lambda_{max}} = \sum(1.25 + 01.29 + 0.33 + 1.11 + 0.72 + 0.37 + 0.87 + 0.29 + 1.60 + 2.70 + 1.77 + 1.55 + 2.65 + 0.49 + 0.96 + 1.79 + 0.17) = \mathbf{19.90} \quad \text{(S1)}$$

Next, the Consistency Index (CI) was calculated using Equation S2. The CI of a nxn matrix is defined by:

$$\boldsymbol{CI} = \frac{\lambda_{max} - n}{n - 1} \quad \text{(S2)}$$

Where n is the number of entries in the matrix. Next, the random consistency index (RI), which depends on n was calculated using Equation S3.

$$\boldsymbol{RI} = 1.98 * \frac{n - 2}{n} \quad \text{(S3)}$$

Finally, CR defined as the ratio of the consistency index (CI) to the random consistency index (RI) was calculated (Equation S4).

$$\boldsymbol{CR} = \frac{CI}{RI} \quad \text{(S4)} \quad \text{(S4)}$$

In this case,

$$\boldsymbol{CI} = \frac{\lambda_{max} - n}{n - 1} = \frac{19.90 - 17}{17 - 1} = \mathbf{0.18}$$

$$\boldsymbol{IR} = 1.98 * \frac{n - 2}{n} = 1.98 * \frac{17 - 2}{17} = \mathbf{1.75}$$

$$\boldsymbol{CR} = \frac{CI}{IR} = \frac{0.18}{1.75} = 0.10 \approx \mathbf{10}\%$$

Since our CR was 10%, the estimation of the attribute weights was acceptable.

2. Sustainability score of the rural water supply system

Table S5 presents the sustainability score obtained for the rural water supply system assessed in the case study.

Table S5. Synthesis of the sustainability score for the rural water supply system.

Number	Attribute	$\sum(\boldsymbol{W_i} * \boldsymbol{S})$	Wa	$\boldsymbol{W_a} * \left[\sum(\boldsymbol{W_i} * \boldsymbol{S})\right]$
1	Population characteristics	1.7	0.06	0.11
2	Users acceptability	4.8	0.06	0.30
3	Accountability and transparency	4.0	0.02	0.07
4	Collective action	2.6	0.06	0.15
5	Conflicts	2.9	0.04	0.10
6	Policies, rules, and norms	1.0	0.02	0.02
7	Administration, operation, and maintenance	2.7	0.04	0.12
8	Post-construction support	1.2	0.01	0.02
9	Access to water	4.3	0.08	0.35
10	Appropriate Technology	5.0	0.13	0.67
11	Infrastructure	1.1	0.09	0.10

Number	Attribute	$\sum(W_i * S)$	Wa	$W_a * \left[\sum(W_i * S)\right]$
12	Reliability	4.7	0.08	0.35
13	Water quality	1.0	0.14	0.14
14	Financial knowledge	1.0	0.02	0.02
15	Funding	1.7	0.05	0.08
16	Risks to service provision	3.5	0.09	0.32
17	Environmental impact of Technology	4.7	0.01	0.04
	Sustainability score			3.0

Notes: Wi: Weight of indicator; S: Score; Wa: Weight of attribute

In Section 2.1, the rating and assessment of each attribute is further detailed.

2.1. Rating and assessment of attributes for the case study

Table S6. Population characteristics.

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
Percentage (%) of people that have completed high school (1.1)	0.05	The educational level of the community facilitates system functioning	HS	Only 12% of SR had a high school or above level of education.	1	0.05
Population growth rate (%) (1.2)	0.20	Population growth is not a hazard for the system capacity in the short-term	TL	Population growth was 4%, which could be an issue and a pressure factor due to the fragile páramo ecosystem.	1	0.20
Percapita water demand/World Health Organization standard (100 lpcd) [2] (1.3)	0.50	User water practices are not a hazard for the system capacity in the short-term	WM	Water demand was 740 lpcd. With increasing population growth (4%) and productive uses of water, water provision could be at risk if water management strategies are not considered.	1	0.50
Percentage (%) of users who have been trained in water, sanitation, and hygiene issues (1.4)	0.05	Users have been trained in water, sanitation, and hygiene issues	HS	0% of SR had received training in water, sanitation, and hygiene issues.	1	0.05

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
Percentage (%) of users who understand how the system is managed (1.5)	0.05	Users understand how the system is managed	HS	52% of SR indicated they understood how the system was managed.	3	0.15
Percentage (%) of users who understand how the system is operated and maintained (1.6)	0.05	Users understand how the system is operated and maintained	HS	68% of SR indicated they understood how the system was operated and maintained.	4	0.20
Percentage (%) of users who believe they are able to pay for the water service (1.7)	0.1	Users believe they are able to pay for the water service	HS	97% of SR indicated they were able to pay for the water service.	5	0.50
$\sum(Wi * S)$						1.7

Notes: HS: Household Survey; SR: Survey Respondents; TL: Timeline; WM: Water Monitoring; O: Observation; SI: Sanitary Inspection

Table S7. Users acceptability.

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi* S
Percentage (%) of users who are satisfied with water quality (2.1)	0.20	Users are satisfied with water quality	HS	SR indicated water quality varied from good to excellent; 60% in rainy season and 80% in dry season.	4	0.80
Percentage (%) of users who are satisfied with water quantity (2.2)	0.35	Users are satisfied with water quantity	HS	83% of SR indicated they were satisfied with the quantity of water provided.	5	1.75
Percentage (%) of users who are satisfied with service reliability (2.3)	0.20	Users are satisfied with system reliability	HS	89% of SR indicated they were satisfied with system reliability.	5	1.0
Percentage (%) of users who have not experience illness perceived to be	0.05	Users have not experience illness perceived to be related to water	HS	92% of SR indicated they had not experienced illness perceived to be related to water.	5	0.25

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi* S
related to water (2.4)						
Percentage (%) of users who are willing to pay for the water service (2.5)	0.20	Users are willing to pay for the water service	HS	95% of SR expressed willingness to pay for the service, 68% would pay $1.8 USD or more.	5	1.00
$\sum(Wi * S)$						4.8

Notes: HS: Household Survey; SR: Survey Respondents

Table S8. Accountability and transparency.

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
Existence of democratic mechanisms to choose water committee members (3.1)	0.25	Users choose water committee members	FG; SSI	Committee members were volunteers who had assumed system responsibility based on their willingness to serve.	1	0.25
Number of times in the last year the water committee met users (3.2)	0.25	Water committee meets with users	FG; SSI	Water committee met users regularly, especially for decision-making.	5	1.25
Percentage (%) of users who know rules for access and use of the service (3.3)	0.25	Community knows the rules for access and use of the water service	FG; SSI; HS	The community knew the rules for access and use of the water service. For instance, 100% SR expressed not using water from the system for irrigation. However, the demand found (740 lpcd) suggests users were not fulfilling the rules they agreed.	5	1.25
Existence of mechanisms to inform users about committee	0.25	Community knows committee finances and use of funds	FG; SSI	The community was informed when money was collected and how it was invested.	5	1.25

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
finances and use of funds (3.4)						
$\sum(Wi * S)$						4.0

Notes: HS: Household Survey; SR: Survey Respondents; FG: Focus Groups; SSI: Semi-structured interviews.

Table S9. Collective action.

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
Percentage (%) of users who participate in administration activities (4.1)	0.05	Users participate in administration activities	HS; FG; SSI	18% of SR indicated they had participated in administration activities.	3	0.15
Percentage (%) of users who participate in the planning and construction of the system (4.2)	0.05	Users participated in defining system characteristics	HS; FG; SSI	20% of SR expressed the community participated in system design. In the FG, leaders explained this did not happen and this participation occurred when the builders abandoned the unfinished system and the community took over.	1	0.05
Number of initiatives developed by institutions with active community participation in the last year (4.3)	0.05	Users trust in institutions	FG; SSI; TL	The community had little trust in external institutions due to bad previous experiences and to the latent conflict to regulate the development of productive activities in the páramos.	1	0.05
Percentage (%) of users who participate by contributing in cash to the system (4.4)	0.35	Users participate by contributing in cash to the system	HS	26% of SR indicated they had participated by contributing in cash to the system.	2	0.70

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
Percentage (%) of users who participate by supporting O&M activities (4.5)	0.10	Users participate by supporting O&M activities	HS; FG; SSI	35% of SR indicated they had participated by supporting O&M activities.	2	0.20
Percentage (%) of users who believe woman participate in all aspects of system management (4.6)	0.05	Woman participate in all aspects of system management	HS; FG; SSI	37% of SR indicated they believe woman participate in all aspects of system management.	2	0.10
Percentage (%) of users who participate in meetings (4.7)	0.20	Users participate in meetings	HS; FG; SSI	46% of SR expressed they participate in meetings	3	0.60
Percentage (%) of users who believe they are listened to and their opinions are respected (4.8)	0.05	Users believe they are listened to and their opinions are respected	HS	86% of SR indicated they believe they were listened to and their opinions were respected.	5	0.25
Number of initiatives undertaken for the committee regarding system improvement in the last year (4.9)	0.05	Leaders take the initiative to improve the system	FG; SSI; TL	The construction of the system was initiated by an external entity, but it was not finished. The initiative of local leaders resulted in the collection of funds from the community to complete the system, without any external support.	5	0.25
Percentage (%) of users who are willing to participate in activities related to the system (4.10)	0.05	Users are willing to participate in activities related to the system	HS; FG; SSI	89% of SR expressed they were willing to participate in activities related to the system.	5	0.25
$\sum(Wi * S)$						2.6

Notes: HS: Household Survey; SR: Survey Respondents; FG: Focus Groups; SSI: Semi-structured interviews; TL: Timeline.

Table S10. Conflicts.

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
Existence of institution-human conflicts over water sources (5.1)	0.30	There are no chances of institution-human conflicts over water sources	FG; SSI; TL	Local leaders expressed a latent conflict with users that utilize water from the system for irrigation.	2	0.60
Existence of effective conflict resolution mechanisms (5.2)	0.40	There are conflict resolution mechanisms	FG; SSI; TL	Community leaders indicated they talked to users if there was evidence of "inadequate" water management, but apparently this mechanism had not been effective. The conflict due to human activities and the use of resources in the páramo ecosystem was latent; the environmental authority and the government implemented strategies that lacked community acceptance.	2	0.80
Percentage (%) of users who have not experienced conflicts with other users regarding water (5.3)	0.30	There are no chances of human-human conflicts over water sources	HS; FG; SSI	98% of SR reported had not experienced conflicts due to water.	5	1.50
$\sum(Wi * S)$						2.9

Notes: HS: Household Survey; SR: Survey Respondents; FG: Focus Groups; SSI: Semi-structured interviews; TL: Timeline

Table S11. Policies, rules and norms.

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
(Number of regulations fulfilled / Number of applicable regulations) × 100 (6.1)	0.3	System meets national and local legal requirements	FG; SSI	Colombian regulations for water service providers were not met. The leaders ignored some of these requirements or the process to fulfil them.	1	0.3
Existence of water rights (6.2)	0.7	System has water right	FG; SSI	The system lacked water right.	1	0.7
$\sum(Wi * S)$						1.0

Notes: FG: Focus Groups; SSI: Semi-structured interviews.

Table S12. Administration, Operation, and Maintenance.

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
Existence of a legally registered water committee (7.1)	0.02	The water committee is legally registered	FG; SSI	The water committee was not legally registered.	1	0.02
Existence of a functional water committee (7.2)	0.15	The water committee is functional	FG; SSI	The water committee was functional.	5	0.75
Existence of water committee bylaws (7.3)	0.01	The water committee has bylaws	FG; SSI	The water committee lacked bylaws.	1	0.01
(Active water committee members / Total number of committee members) × 100 (7.4)	0.01	All water committee members are actively involved	FG; SSI	All water committee members were actively involved.	5	0.05

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
Existence of an effective mechanism for the rotation of the water committee members (7.5)	0.01	Water committee members rotate	FG; SSI	Water committee members were a small group of people who had taken over the system management due to a lack of interest among others to assume responsibilities beyond performing occasional maintenance tasks or making occasional economic contributions.	1	0.01
(Number of water committee members trained in water management / Total number of committee members) × 100 (7.6)	0.12	Water committee members are trained	FG; SSI	The water committee members had not received any training regarding water service management and provision.	1	0.12
(Number of female water committee members / Total number of committee members) × 100 (7.7)	0.01	Water committee includes female members	FG; SSI	A third of water committee members were women.	5	0.05
Existence of rules for access and use of the water service (7.8)	0.1	Rules have been set for access and use of the water service	FG; SSI	Rules for access and use of the service were established democratically with user participation. For instance, rules had been developed for connections, operation and management,	5	0.5

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
				and on restrictions on the use of water for irrigation.		
Existence of mechanisms for enforcement of rules for access and use of the water service (7.9)	0.1	Rules for access and use of the water service are enforced, and monitoring and sanctioning processes are in place	FG; SSI; O	Rules for access and use of the water service were not enforced, monitored, or sanctioned. There were no mechanisms and resources for any of these activities.	1	0.1
Existence of an office for the water committee (7.10)	0.01	Water committee has an office	FG; SSI; O	The water committee lacked an office.	1	0.01
Existence of strategies for asset reposition (7.11)	0.01	Water committee develops strategies for asset reposition	FG; SSI; O; SI	The water committee did not develop strategies for asset reposition.	1	0.01
Existence of good written records (7.12)	0.03	Water committee keeps good written records	FG; SSI; O	The water committee only kept records of occasional financial contributions from users when reparations were needed.	1	0.03
Number of effectively solved user complaints / Total number of complaints (7.13)	0.02	User complaints are effectively addressed by the water committee	FG; SSI; O	The water committee lacked a system for receiving and addressing user complaints.	1	0.02
Annual frequency of operation and maintenance activities (7.14)	0.1	Operation and maintenance activities are developed	FG; SSI; O; SI	Operation and maintenance activities were developed by a small group of volunteers, but the frequency was low.	3	0.3

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
Existence of a functioning caretaker or maintenance committee (7.15)	0.1	The system has a caretaker or maintenance committee	FG; SSI; O; SI	The system had a small group of volunteers that assumed operation and maintenance activities. They were able to perform artisanal minor and major repairs.	5	0.5
Number of trainings received by the caretaker or the maintenance committee in the last five years (7.16)	0.1	The caretaker or maintenance committee level of training is adequate	FG; SSI	The small group of volunteers that develop operation and maintenance activities had not received any training. They had empirical knowledge.	1	0.1
Existence of a salary or compensation for the caretaker or maintenance committee (7.17)	0.1	The caretaker or maintenance committee receives compensation	FG; SSI	The small group of volunteers did not receive compensation for their work.	1	0.1
$\sum(Wi * S)$						2.7

Notes: FG: Focus Groups; SSI: Semi-structured interviews; O: Observation; SI: Sanitary Inspection

Table S13. Post-construction support.

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
Amount of money or in-kind resources received by users or water committee from government or NGOs in the last year (8.1)	0.1	Users or water committee receive financial resources from government or NGOs	FG; SSI; O	Users or water committee did not receive financial resources from government or NGOs.	3	0.3

Sustainability indicator	**Weight of indicator (Wi)**	**Qualitative value judgement**	**Data collection method**	**Behavior in the case study**	**Score (S)**	**Wi*S**
Technical/ administrative/ financial training received by users or water committee from government or NGOs in the last year (8.2)	0.7	Users or water committee receive technical/ administrative/ financial training from government or NGOs	FG; SSI; O	Users or water committee had not received technical/ administrative/ financial training from government or NGOs.	1	0.7
Technical/ administrative/ financial support received by users or water committee from government or NGOs in the last year (8.3)	0.2	Users or water committee receive technical/ administrative/ financial support from government or NGOs	FG; SSI; O	Users or water committee had not received technical/ administrative/ financial support from government or NGOs.	1	0.2
$\sum(Wi * S)$						1.2

Notes: FG: Focus Groups; SSI: Semi-structured interviews; O: Observation; NGOs: Non-governmental Organizations

Table S14. Access to water.

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
(Households provided / Total households in the village) × 100 (9.1)	0.7	System provides all the households in the village	FG; SSI; SI; O	91% of households in the community obtained water from the system through household connections. The remaining households were not served due to pressure limitations, but these households had their own surface sources.	4	2.8
(Household connections / Households provided) × 100 (9.2)	0.3	System provides water through piped household connections	HS; FG; SSI	100% of households had piped household connections with several taps.	5	1.5
$\sum(Wi * S)$						4.3

Notes: HS: Household Survey; FG: Focus Groups; SSI: Semi-structured interviews; O: Observation; SI: Sanitary Inspection

Table S15. Appropriate Technology.

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
Distance and type of road to the nearest urban center (10.1)	0.2	An urban center is easily accessible from the village	O	The village is 55 Km from a main urban center accessible through a paved road.	5	1
Number of mechanical and electrical parts in the system (10.2)	0.2	System does not have too many complex parts	FG; SSI; SI; O	The system did not have mechanical or electrical parts that make its operation complex.	5	1
Number of system parts that are locally available /	0.2	System parts are locally available	FG; SSI; SI; O	The system only required pipes and	5	1

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
Number of total parts (10.3)				materials of easy acquisition at the local level.		
Number of system parts that are affordable to the community / Number of total parts (10.4)	0.2	System parts are affordable	FG; SSI; SI; O	The system did not include expensive parts.	5	1
Amount of non-renewable energy required for system functioning (Kw) (10.5)	0.2	System does not use non-renewable energy sources	FG; SSI; SI; O	The system was gravity-fed and did not include equipment requiring non-renewable energy for its operation.	5	1
$\sum(Wi * S)$						5.0

Notes: FG: Focus Groups; SSI: Semi-structured interviews; O: Observation; SI: Sanitary Inspection

Table S16. Infrastructure.

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
Demand used for design / Actual demand (11.1)	0.4	Users water needs are compatible with system design	WM; FG; SSI	The system was designed for domestic purposes and was used for domestic and productive activities.	1	0.4
Components properly designed / Total components (11.2)	0.1	System components were properly designed	FG; SSI; SI; O	The system failed to meet most of the technical standards in all the infrastructure components.	1	0.1
Components properly built / Total components (11.3)	0.1	System was built according to its design	FG; SSI; SI; O	Designs were not available at any government entity or in the community.	1	0.1

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
				Therefore, it was not possible to check these criteria.		
Length of fencing / Required length of fencing (11.4)	0.1	System source is protected	FG; SSI; SI; O	System source was unprotected. There was no fence and grazing animals accessed and defecated in and around the intake, grit camber, and water storage tanks.	1	0.1
Properly designed treatment components / Total components (11.5)	0.05	Treatment system was properly designed	FG; SSI; SI; O	There was no treatment system.	1	0.05
Properly built treatment components / Total components (11.6)	0.05	Treatment system works properly	FG; SSI; SI; O	There was no treatment system.	1	0.05
Number of visible leaks (11.7)	0.05	System does not have significant water losses	FG; SSI; SI; O	The system had some leaks in the pipes and spills occurred at certain times in the grit chamber and storage tank.	3	0.15
Number of components with an age below its estimated lifetime / Total components (11.8)	0.1	System components have not exceeded their lifetime	FG; SSI; SI; O	The system was 5 years old, but the built infrastructure fell short of the current demand. The community adapted an artisanal additional transmission pipe, but this made the grit	1	0.1

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
				chamber ineffective and resulted in spills in the storage tank during low-demand hours.		
Percentage (%) of users who have working customer meters (11.9)	0.05	Users water consumption is periodically recorded	HS; FG; SSI	User water consumption was not periodically recorded.	1	0.05
$\sum(Wi * S)$						1.10

Notes: HS: Household Survey; FG: Focus Groups; SSI: Semi-structured interviews; WM: Water Monitoring; O: Observation; SI: Sanitary Inspection

Table S17. Reliability.

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
Percentage (%) of users that receive water 24 hours a day in dry season (12.1)	0.4	System provides water 24 hours a day for all users in dry season	HS; FG; SSI	83% of SR indicated the system provided water in the dry season.	5	2
Percentage (%) of users that receive water 24 hours a day in rainy season (12.2)	0.3	System provides water 24 hours a day for all users in rainy season	HS; FG; SSI	97% of SR indicated the system provided water in the rainy season.	5	1.5
Percentage (%) of users that have not experienced failures in water provision in the last year (12.3)	0.05	Failures do not occur in service provision	HS; FG; SSI	55% of SR indicated failures occurred in service provision, mainly pipe breaks.	3	0.15
Percentage (%) of users who believe that when the service gets disrupted, it is quickly repaired (12.4)	0.05	When the service gets disrupted, it is quickly repaired	HS; FG; SSI	61% of SR indicated that when the service got disrupted, it was quickly repaired.	4	0.2
Percentage (%) of users who believe water	0.2	Water pressure is adequate for all users	HS; FG; SSI	69% of SR indicated water pressure was adequate.	4	0.8

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
pressure is adequate (12.5)						
$\sum(Wi * S)$						4.7

Notes: HS: Household Survey; SR: Survey Respondents; FG: Focus Groups; SSI: Semi-structured interviews

Table S18. Water quality.

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi* S
Percentage (%) of water samples without *Escherichia coli* (*E. coli)* (13.1)	0.8	System provides safe water	WM	*E.coli* counts were present in 100% of samples at the source and at household taps, in both the dry and rainy season.	1	0.8
Percentage (%) of water samples with turbidity below 2 Nephelometric Turbidity Units (NTU) (13.2)	0.2	System provides safe water	WM	Samples outside the quality standard for turbidity in the dry season were 50% at the source and 100% at the households, while in the rainy season the non-compliance was 75% at source and 100% at households.	1	0.2
$\sum(Wi * S)$						1.00

Notes: WM: Water Monitoring

Table S19. Financial knowledge.

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
Existence of an annual budget for the system (14.1)	0.2	Water committee budgets system revenues and expenses	FG; SSI; O	The water committee did not establish a budget for system revenues and expenses. The water committee knew costs of occasional repairs. However, they ignored the costs to provide an improved service (staff, water rights, taxes, O&M, etc.)	1	0.2
Number of financial training sessions received in the last five years (14.2)	0.3	Water committee has received financial training	FG; SSI; O	Water committee had never received financial training.	1	0.3
Existence of a fund with enough resources to carry out operation and maintenance activities (14.3)	0.3	Operation and maintenance costs can be met by the water committee	FG; SSI; O	There was no money for recurring expenses and there was not a fund for O&M. All work was done through volunteers without financial compensation.	1	0.3
Existence of a fund with enough resources for investments in system improvements (14.4)	0.2	Investment costs can be met by the water committee	FG; SSI; O	There was no money for investments. Repairs and improvements were made with sporadic contributions. There were some remaining savings from contributions, but those were limited since typically, the exact amount of money needed for the investments was requested to users.	1	0.2
$\sum(Wi * S)$						1.00

Notes: FG: Focus Groups; SSI: Semi-structured interviews; O: Observation; O&M: Operation and Maintenance

Table S20. Funding.

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
Existence of a fee for water service linked to volume consumed, and with charges according to socioeconomic levels (15.1)	0.3	Fees have a structure that promotes the efficient use of water and equity	FG; SSI; O	There was no fee for the water service.	1	0.3
Existence of payment records (15.2)	0.05	Fee payment records are kept	FG; SSI; O	Not applicable	1	0.05
Percentage (%) of users who are up to date with payments (15.3)	0.05	All users timely pay the fee	FG; SSI; HS	Not applicable	1	0.05
Percentage (%) of users for whom fees for basic supply is up to 3.5% of monthly household income (15.4)	0.2	Fee is affordable for all users	FG; SSI; HS	Not applicable	1	0.2
Existence of sanctions for late or non-payment (15.5)	0.05	Households are fined for late payment, and/or disconnected for non-payment	FG; SSI; O	Not applicable	1	0.05
Revenue / Budgeted needs during the last year (15.6)	0.35	Revenue is sufficient to cover system needs	FG; SSI	The money collected through extraordinary contributions was sufficient for some investments and minor repairs but not for the substantial improvements required by the system in terms of infrastructure, administration, operation, and maintenance.	3	1.05

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
$\sum(Wi * S)$						1.7

Notes: HS: Household Survey; FG: Focus Groups; SSI: Semi-structured interviews; O: Observation

Table S21. Risks to service provision.

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
Water demand during the dry season projected for 20 years / Yield at source (dry season) (16.1)	0.5	The source has enough yield to meet demand throughout the year	WM	The source provided 18 [L / s] (dry season) and 19 [L / s] (rainy season) and the peak demand in the system was 3 [L/s].	5	2.5
Absence of human activities (e.g. agriculture, industry, human settlements, mining, etc.) with potential to pollute the water source (16.2)	0.3	The system does not have livestock grazing activities with potential pollution sources near to the water source	SI	There were grazing activities around the intake, grit chamber, and storage tank. Livestock had free access to these areas, thus creating a potential pollution threat.	1	0.3
Absence of landslides threaten infrastructure components (16.3)	0.1	There are no natural threats to the system	SI	In most of its length, the main pipe was not buried. At some points, the network went through places where there was a landslide risk.	2	0.2
Percentage (%) of users that utilise alternative water sources (16.4)	0.1	There are alternative water sources easily accessible to the community	HS; O	98% of SR indicated having access to alternative water sources they used for irrigation and animal watering.	5	0.5
$\sum(Wi * S)$						3.5

Notes: HS: Household Survey; SR: Survey Respondents; WM: Water Monitoring; O: Observation; SI: Sanitary Inspection

Table S22. Environmental impact of technology.

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
Volume of wastewater in a year / Volume of water supplied in a year (17.1)	0.15	The system does not generate wastewater	WM	Wastewater was generated once a month when tanks were washed. Wastewater was discharged to the source, downstream.	3	0.45
Area occupied by the system / Volume of water supplied in a year (17.2)	0.1	The system uses a low amount of land	SI; WM	The system used a low amount of land, since the only infrastructure was the intake, grit chamber, and a storage tank.	5	0.5
(Water abstracted in dry season / Yield at source in dry season) × 100 (17.3)	0.4	The system does not deplete the water source	WM	The system only used 17% of the flow available at the source in the dry season, leaving water in the channel for downstream uses and preservation of the water body.	5	2
Tons of solid waste produced in a year / Volume of water supplied in a year (17.4)	0.1	The system does not produce solid waste	SI; WM	The system did not produce solid waste.	5	0.5
Tons of atmospheric emissions produced in a year / Volume of water	0.1	The system does not produce atmospheric emissions	SI; WM	The system did not produce atmospheric emissions.	5	0.5

Sustainability indicator	Weight of indicator (Wi)	Qualitative value judgement	Data collection method	Behavior in the case study	Score (S)	Wi*S
supplied in a year (17.5)						
Decibels generated in a year / Volume of water supplied in a year (17.6)	0.05	The system does not generate noise	SI; WM	The system did not generate noise.	5	0.25
kW of non-renewable energy used in a year / Volume of water supplied in a year (17.7)	0.1	The system does not use non-renewable energy	SI; WM	The system did not use non-renewable energy.	5	0.5
$\sum(Wi * S)$						4.7

Notes: WM: Water Monitoring; SI: Sanitary Inspection

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